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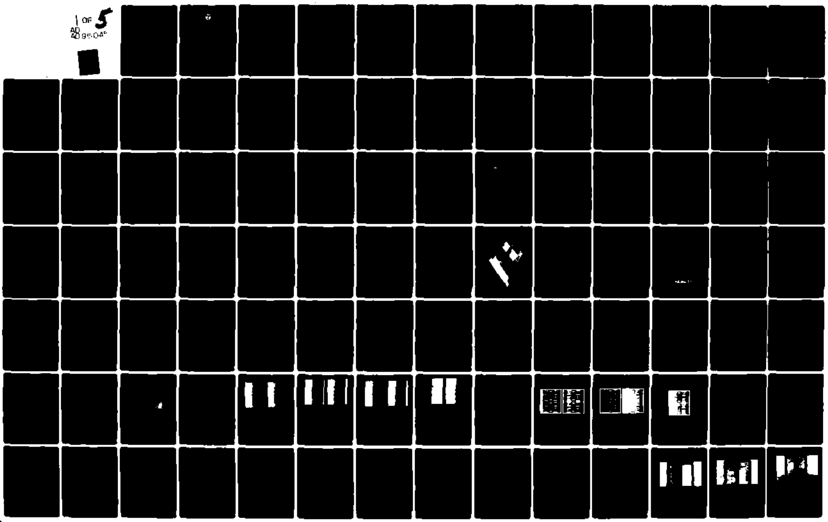

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RIGID-FLEX PRINTED CIRCUIT MANUFACTURING PROCESS

A project of the Manufacturing Technology Program

Naval Sea Systems Command

30 June 1979

Prepared by

J.A. Reavill,
General Dynamics
(N00123-77-1192)

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AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

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ADMINISTRATIVE INFORMATION

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This report describes all activities which were performed while developing a manufacturing process to fabricate Rigid-Flex printed wiring cables constructed with polyimide glass laminate stiffeners and copper/Kapton/acrylic adhesive flexible layers.

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SUMMARY

PROGRAM OBJECTIVES

The rigid-flex printed circuit manufacturing process development program described in this report was performed for the Naval Ocean Systems Center in San Diego, CA., by General Dynamics, Pomona Division. The intent of the program was to improve manufacturing technology so that a substantially better production yield and corresponding cost reduction could be achieved (increase from 60% to 85%). The technology improvement involved substituting polyimide glass laminate stiffeners for the currently utilized epoxy glass laminate stiffeners in order to improve drilling characteristics, prevent thermal damage created by Z-axis expansion, and increase processing uniformity. In addition, a cost saving was expected to result from optimizing individual process parameters.

TECHNICAL APPROACH

The activities performed to achieve the program objectives first involved identifying one of eight different suppliers in order to purchase the polyimide glass laminate. The laminate supplier selection was based upon material testing, cost, quality/technology level, and production capability.

Material was procured and a process investigation was conducted which evaluated current production processes by fabricating and testing sample rigid-flex units.

An optimized fabrication process was developed by varying individual process parameters and the deliverable rigid-flex units were fabricated according to the documented material, process, and product specifications generated during this program.

To establish that the cables meet specification requirements, extensive testing was performed on each unit.

A yield/cost analysis was performed to verify the achievement of program goals.

PROGRAM ACHIEVEMENT

It was established that the polyimide glass laminate which was substituted did provide improved drilling characteristics, reduced Z-axis expansion (54%), and increased compatibility with individual processes.

Process optimization also provided a substantial yield increase as projected (approximately 25%).

In addition, the continually observed phenomenon of bulging and tilting of the laminate, which causes inner circuit separation, appears to be overcome by the combination of optimized processing and polyimide laminate stiffeners.

PREFACE

Advances in manufacturing technology are continuing to be made as both new materials and processing equipment become available. This can be illustrated by examining the results of previous Navy technology development programs directed toward flexible printed circuit processing.

One such program involved the substitution of an acrylic adhesive system for a phenolic butyral adhesive system which made possible a 100% increase in average product yields. This major accomplishment led to the proposal of the technology program presented in the subject report, which also involved a material substitution. In this case a polyimide glass laminate replaces an epoxy glass laminate used for cable stiffeners.

If the prior development program had not been performed, the advances described in this program would not have been possible.

Material suppliers, too numerous to mention here, did provide valuable assistance in several phases of this program and are recognized for their effort. Some of these suppliers are mentioned throughout this report and many products are also described. Only those products which were used successfully are discussed because it is recognized that the others may have performed acceptably under different processing conditions.

It is believed that as more new products, equipment and technologies are investigated and applied, correspondingly more cost effective programs such as the "Rigid-Flex Printed Circuit Manufacturing Process Development Program" will be performed.

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SECTION 1 INTRODUCTION

1.1 PROGRAM ADMINISTRATION

This manufacturing technology program was authorized and funded through the Manufacturing Technology office, Code 05R/2, Mechanics and Materials Division of the Naval Sea Systems Command, Washington, D.C. under the cognizance of Mr. Harry Byron. The technical and administrative direction of the program was provided by the Naval Ocean Systems Center (NOSC), San Diego, CA. Dr. Dean McKee and Clint Spurlin were program monitors.

The work was performed with the Advanced Manufacturing Technology Section at the Pomona Division of General Dynamics, under the direction of Dr. M. C. Abrams. The program was coordinated by R. W. Aubert and the principal investigator was J. A. Reavill.

1.2 PROGRAM OBJECTIVE

The objective is to define and demonstrate an advanced manufacturing process coordinated with an appropriate material system for producing multilayer rigid-flexible printed circuit laminates. The resultant process should be capable of producing parts consistent with the facilities and practices of any standard military printed circuit factory. The resultant parts should show a cost reduction relative to present fabrication, primarily based on improved yields due to the superior material properties as related to the production process.

1.3 BACKGROUND

1.3.1 Rigid-Flex Printed Wiring Cables

Such cables are used in tactical missile systems which are currently being produced by General Dynamics for the Navy. Standard Missile (SM-2) is an example of one tactical missile which has two different configurations of rigid-flex cables incorporated into its design. The concept of rigid-flex cables is not exclusive to tactical missile systems, although several electronic and weapons manufacturers have applied it to such systems. The rigid-flex cable is ideal for applications where high-density, point-to-point circuitry must be used to transmit voltage, signal, or power outputs in limited space envelopes which are not in one plane.

Two different rigid-flex cables are shown in Exhibit 1 in the appendix. The cable at the top (PN 3217116) is used in the SM-2 tactical missile guidance computer and is one of the candidate designs chosen to be fabricated for this program. The cable at the bottom is a test pattern which was fabricated in order to obtain process development information. Both cable configurations were built as part of contract deliverables.

The construction of both cables is shown in Exhibit 2 of the appendix. Each cable is similar in that they consist of eight two-ounce copper circuit layers, three distinct two-sided flex cables, polyimide glass outside stiffeners, and 0.032-inch-diameter plated-through-holes. The SM-2 cable contains only one rigid area with three open leaf flexible cables, which contain plated-through-holes and circuit with conductor widths down to

0.010 inch, and spacing down to 0.009 inch. The test pattern was constructed without dense circuitry or plated holes in the flexible portion so that many units could be fabricated rapidly to obtain process development information.

1.3.2 Technology Improvement

Technology for producing both rigid printed wiring boards and flexible printed wiring cables is available at present which allows most manufacturers to achieve a relatively high yield for normal production lots. The yield is usually dependent on such factors as conductor line widths and spaces, number of plated-through-holes, number of circuit layers, and base material core thickness.

In contrast, the rigid-flex printed wiring cable is usually produced by most manufacturers with extreme difficulty, and low production lot yields. Common production problems which are inherent to rigid-flex production are: cracked plated-through-holes, delamination, trapped air in the laminate, and open circuits between the plated-through-hole and inner circuit layers.

The low yields which manufacturers experience while producing rigid-flex printed wiring cables directly affect the cost of each unit. For example, yields which have often fallen below 50% naturally have actually increased the average cost per unit 100% and more. In order to reduce the excessive production costs resulting from low yields it was necessary to develop the technology needed for more efficient and effective production processes and material combinations.

The manufacturing technology program presented in the report was performed for the Navy in order to develop process and material technology which will increase production yields of rigid-flex cables while reducing costs. The basic technical approach was to substitute the material which is used in the rigid portion of the cable and develop many efficient laminations, drilling, smear removal, and plating processes.

The substitution material used in the rigid portion of the cable is a polyimide glass laminate (replacing epoxy glass laminate). This material was used because of its superior physical properties and its compatibility with production processes. The properties providing improvement in this application are the polyimide's lower Z-axis expansion, relatively smear free drilling characteristics, resistance to elevated temperatures, and common material construction (flexible layers are also polyimide). The improved properties of the polyimide help eliminate cracked plating in holes because of an approximate 60 to 80 percent reduction in Z-axis expansion. Also reduced yields, resulting from open circuits at inner layer and plated-through-hole junctions, are improved because of the superior drilling characteristics. In addition, the higher temperature characteristics of the polyimide prevent delamination both during fabrication and in subsequent assembly operations.

SECTION 2 TECHNICAL APPROACH

As part of the first month's activities in this development program a test plan was written. Exhibit 3 in the appendix contains a copy of the test plan, which describes in detail all activities to be accomplished throughout the program. It also contains a projected schedule showing month by month bench marks of completion.

SECTION 3 WORK ACCOMPLISHED

3.1 MATERIAL AND VENDOR EVALUATION

This portion of the program was directed only toward the polyimide glass laminate material, which is used as outside stiffeners for the rigid-flex cable. The rationale for this was that a previous Navy development program had been performed to evaluate the Kapton*, copper, acrylic adhesive system used for flexible circuitry.

3.1.1 Summary of Work

Eight potential vendors of polyimide glass laminate were contacted to determine their willingness and ability to supply material for this project. Seven of the eight vendors wanted to supply material and are included in this Manufacturing Technology Program.

Plant tours of each vendor's facilities were conducted and all of the facility capabilities were ranked from most to least competent. In addition technical literature was obtained, where possible, to determine advertised material properties.

Test samples of each of the seven vendor's product were requested. Six of the suppliers were actually able to provide the samples in time to be tested.

Selected tests were performed on each of the six supplier samples in order to determine the vendor to be used in the manufacturing phase of this program. Two of the six suppliers were chosen from which to order material for the program based on the results of the tests performed.

3.1.2 Vendor Survey

The "TEST PLAN" submitted in October, 1977 listed eight companies which had at one time manufactured polyimide glass laminates for the printed circuit board industry. As proposed in the test plan, all of the companies were contacted to determine their present manufacturing status and willingness to participate in this Navy program.

The eight companies are listed below:

1. Du Pont de Nemours
   21444 Golden Triangle Rd.
   Saugus, CA 91350
2. Youngblood Laminates
   P.O. 319
   Milbury, MA 01527
3. Synthane Taylor Laminates
   1400 Arrow Hwy.
   La Verne, CA 91750
4. Mica Corporation
   10900 Washington Blvd.
   Culver City, CA 90230
5. Norplex Division (Universal Oil Products Company)
   1300 Norplex Dr.
   La Crosse, Wisconsin 54601

*Kapton is a tradename for a polyimide film, which was developed by DuPont DeNemours, to act as an electrical insulation material exhibiting excellent electrical properties as well as superior resistance to most chemicals and elevated temperatures.

6. Fortin Laminates
   1323 Truman Street
   San Fernando, CA 91340
7. Howe Industries
   13704 Saticoy Street
   Panorama City, CA
8. Atlantic Laminates
   Hoosick Falls, N.Y.

All of these companies, except for Fortin Laminates, are currently supplying polyimide glass laminates to some extent throughout the electronics industry. All of those listed, that are currently supplying polyimide glass laminates, did express the desire to participate in the program and volunteered samples which could be used for test purposes.

During this vendor survey several suppliers discussed information which, they stated, was either confidential or private to their companies. These items will not be discussed in this report. To protect each vendor's position in the market a letter code will be given in reference to the company name. Only GD/P personnel, and possibly certain specific Navy monitors, will know the code.

3.1.2.1 FACILITY TOURS. A trip was made to each of the seven vendors' facilities in order to obtain a relative comparison of manufacturing capability, quality control, material traceability, commitment to the polyimide market, and degree of knowledge in producing printed wiring laminates.

Prior to visiting each of the vendors, a standardized questionnaire and check list was drafted to provide a guideline for the rating of each vendor. The items listed on the check list were felt to be important in evaluating each vendor's relative capability, but it was recognized that other meaningful rating criteria would be obvious as each individual tour was conducted. A sample questionnaire form is shown in the appendix of this report (Exhibit 4).

In conjunction with the tour product specification sheets were obtained, where possible, in order to obtain physical, electrical and chemical property data.

3.1.2.2 FACILITY RANKING. Based on the information obtained for each supplier on their plant tours, they were ranked according to their capabilities, knowledge of processing, quality control systems, degree of traceability and commitment to the market. The sample checklist shown in the appendix was only a guide for rating and does not contain all factors used in the ranking.

The following rankings start with the supplier which appeared to have the most competence and proceed to the one appearing to have the least.

1	G
2	D
3	F
4	C
5	A
6	B
7	E

Note: The code letters are assigned to each supplier and are known only to GD/P personnel and the Navy monitor.

The information obtained during each individual plant tour is not listed in this report so that no "company private" information is disseminated.

3.1.3 Material Testing (Polyimide Glass Laminate)

3.1.3.1 TEST SAMPLES. A request was made to each vendor to supply two sheets of 0.010-inch-thick core single copper clad (1 oz copper) polyimide glass laminate in sheet sizes of 24 in. x 36 in. or longer. This sheet size was selected to prevent any vendor from producing a "laboratory sample" instead of a "production sample."

All of the vendors promised to have their samples delivered to General Dynamics by the end of November, 1977. Actually only six of the samples were received in time to perform the test. At least one full-size sheet was received from each of the six vendors mentioned. Each vendor was required to supply their own particular construction information, referring to the style of glass cloth, the polyimide resin type and type of copper foil used.

Common to all test samples supplied was the resin type. It was Kermid 601 polyimide produced by Rhodia, Inc. This resin is the only commercially available system at present.

Also in common, all vendors supplied the laminate with 2 plies of #116 style sylane finish glass cloth. This point was confirmed by burning off the resin and examining the cloth for thickness and construction. Shown in Exhibit 5 are typical cloth plies.

The cloth each vendor used could have been manufactured by a number of suppliers, however, it is not apparently important according to most laminators. Listed below are typical sources of glass cloth.

1. Uniglass Industries, Division United Merchants Inc.
2. Clark Schweble Fiberglass Corp.
3. Burlington Glass Fabrics Co, Division Burlington Industries & Mfrs Inc.
4. Nichimen Co. Inc.
5. J. P. Stevens and Co. Inc.

The copper foil used by the laminators was produced either by the Gould Co. (Designated Gould-TC) or by the Yates Company. After checking the bonded surface roughness (toothing) of each laminator's copper by cross sectioning, it was apparent that there was a substantial difference in the foil used by each vendor. Shown in Exhibit 6 are the various surface conditions of each vendor's copper treatment. Coded letters are used to identify each particular vendor.

Samples of an epoxy fiberglass laminator were tested along with the polyimide glass samples so that a comparison could be made of the two kinds of materials.

3.1.3.2 TEST PROCEDURES AND RESULTS FOR SUPPLIER SAMPLES. Fifteen tests were selected to choose the best material suppliers. Listed below are all tests used in this evaluation. These tests were taken from tables 4-1, 4-2, and 4-3 of the subject contract statement of work plus other applicable ones.

	Test	Paragraph	Specification
1.	Visual		
	a. Pits and Dents	3.3.2	MIL-P-55617B
	b. Color	3.3.5	MIL-P-55617B
2.	Scratches	3.3.3	MIL-P-55617B
3.	Dimensions	3.3.4	MIL-P-55617B
	a. Length and Width		
	b. Thickness		
4.	Surface Finish of Foil	3.4	MIL-P-55617B
5.	Etching Characteristics	3.5.2	MIL-P-55617B
6.	Solder Dip Before Etching	3.5	MIL-P-55617B
7.	Solder Dip After Etching	3.5	MIL-P-55617B
8.	Machinability	3.3.1	MIL-P-55617B
	a. After Etching		
	b. After Elevated Temperature		
9.	Dimensional Stability	Table III	MIL-P-55617B
10.	Peel Tests as Received	Table III	MIL-P-55617B
11.	Peel Tests After Solder Dip	Table III	MIL-P-55617B
12.	Peel Tests After Exposure to Plating Solutions	Table III	MIL-P-55617B
13.	Peel Tests After Elevated Temperature	Table III	MIL-P-55617B
14.	Peel Tests of Kapton Laminated to Polyimide Glass		
15.	Plating Over Plasma-Treated Surface		

3.1.3.3 VISUAL. Visual inspection of samples supplied by the six vendors showed that all materials were acceptable per MIL-P-55617B for pits, dents, color and clarity of the laminate. However there was a discoloration of the laminate along the borders of three vendors' sheets of material. This can be seen in Exhibit 7. One of the vendors submitted their material too late to get photographed but it looked similar to vendor marked "G". The photographs show 9 in. x 12 in. sheets of material with a standard test peel test pattern etched in the copper.

In ranking the six vendors for the visual qualities mentioned they compared as shown below with No. 1 appearing to be best and No. 6 the worst.

1. F
2. B
3. E — Company names have been coded
4. A
5. D
6. G

3.1.3.4 SCRATCHES. All six vendor materials were acceptable per MIL-P-55617B for scratches with none containing scratches approaching the 140 microinch maximum depth.

3.1.3.5 DIMENSIONS. The length and width dimensions of all sheets submitted were acceptable to MIL-P-55617B requirements. The thickness dimension was also acceptable for all vendors, except one. The nominal overall thickness for the 0.010-inch core material would be 0.0114-in. and the upper limit

is 0.0134 inch (we asked for the ±0.002-inch tolerance material). The one vendor's material ran 0.0135-in. in areas.

In ranking the vendors for being closest to the nominal thickness dimension of the 0.0114-inch their relationship stands as follows with No. 1 the closest and No. 5 the most distant dimension.

1. B
2. F, A
3. E — Company names have been coded
4. D
5. G

The actual measurements obtained for each vendor's material are shown in Exhibit 8.

3.1.3.6 SURFACE FINISH OF FOIL. The maximum surface roughness for the copper foil as allowed by MIL-P-55617B is 20 microinches. As can be seen in exhibit 8 all of the vendor samples were within acceptable limits. No ranking for laminate suppliers was made for this test because of the variation in values obtained and because of the statistically overlapping values. No real meaning could be obtained in comparing such values.

3.1.3.7 ETCHING CHARACTERISTICS. All samples supplied by the six laminators had excellent etching characteristics. No copper particles were left on the laminate after etching and the laminate was not degraded by etching solutions. This characteristic was equal for all the laminators.

3.1.3.8 SOLDER DIP BEFORE ETCHING. All samples supplied by the six laminators withstood the solder dip test per MIL-P-55617B without failure. None of the samples showed evidence of lifting foil, delamination of the laminate, measling, charred or melted resin surface, blistering or any other form of degradation.

3.1.3.9 SOLDER DIP AFTER ETCHING. Test samples etched as shown in exhibit 7 were tested per MIL-P-55617B. The results were identical to those obtained before etching.

3.1.3.10 MACHINABILITY. All six laminators' samples were subjected to sawing, shearing, and drilling operations and none of them cracked, split, or tore as a result. In addition, the drilled holes were plated through with acid sulfate copper and cross sectioned to determine roughness. Exhibit 9 shows each supplier's laminate in the plated-through hole.

3.1.3.11 DIMENSIONAL STABILITY. Samples of each supplier's laminate were tested for dimensional stability per MIL-P-55617B, the only exception being that one 11 in. x 11 in. sample was taken from the sheet edge and one 11 in. x 11 in. sample was taken from the sheet center. The measuring equipment used was very accurate and repeatable. A Burrow Dale Opti-plot was used in conjunction with a Circon Micro-tech video system (50 X TV viewing screen) and Heidenhain digital readout to measure hole distances. The accuracy and repeatability of this system is better than 0.0002 in. The holes to be measured were drilled on a tape controlled digital drilling machine (Excellon Mark III). A stabilizing period of from 2 to 24 hours was given to the samples after etching and baking prior to all measurements.

Only three of the six suppliers were able to pass the dimensional stability test after etching the copper from the test panel. Shown below is the ranking of the six suppliers with No. 1 being best and No. 6 worst.

1. G Passed test
2. A Passed test
3. F Passed test
4. E Passed test
5. D
6. B

Actual test data is contained in Exhibit 8.

Only one of the six suppliers was able to pass the dimensional stability test after exposure to elevated temperature. Shown below is the ranking of the six suppliers with No. 1 being best and No. 6 worst.

1. A
2. G
3. F
4. E
5. D
6. B

Actual test data is contained in Exhibit 8.

3.1.3.12 PEEL TEST - AS RECEIVED. Copper foil strips were peeled from test samples prepared as shown in Exhibit 7. The test patterns were taken from both light- and dark-colored areas in the laminate to detect any difference in properties. There were no major noticeable differences detected.

The ranking of each supplier is shown below with No. 1 rated best and No. 6 worst.

1. B
2. F
3. A
4. D
5. G
6. E

Actual peel strength values are shown in Exhibit 8.

3.1.3.13 PEEL TESTS - AFTER SOLDER DIP. Copper foil strips were peeled from the base material after immersing the samples in molten solder (500°F) for 20 seconds.

The ranking of each supplier is shown below with No. 1 rated best and No. 6 worst.

1. B
2. D
3. F
4. A
5. G
6. E

Actual peel strength values are shown in Exhibit 8.

3.1.3.14 PEEL TESTS - AFTER ELEVATED TEMPERATURE EXPOSURE. Copper foil strips were peeled from the base material after exposure to 204°C for 60 +6 -0 minutes.

The ranking of each supplier is shown below with No. 1 rated best and No. 6 worst.

1. F
2. B
3. D
4. A
5. G
6. E

Actual peel strength values are shown in Exhibit 8.

3.1.3.15 PEEL TESTS - AFTER PLATING SOLUTION EXPOSURE. Copper foil strips were peeled from the base material after exposure to the chemical solutions outlined in paragraph 4.7.5.5 of MIL-P-55617B.

The ranking of each supplier is shown below with No. 1 rated best and No. 6 worst.

1. D
2. A
3. B
4. G
5. E
6. F

Actual peel strength values are shown in Exhibit 8.

3.1.3.16 PEEL TESTS OF KAPTON BONDED TO POLYIMIDE GLASS LAMINATE WITH ACRYLIC ADHESIVE. Test panels of the construction shown in Exhibit 10 were laminated. The Kapton and polyimide glass were pretreated with a gas plasma prior to lamination. The construction is similar to that used in the SM-2 rigid-flex printed wiring cable as can be seen in Exhibit 2.

The test panels were cut into 1 in. wide strips using a Thwing process sample cutter to assure smooth edges. Half of each test strip was dipped into molten solder for 20 seconds at 550°F. These coupons were peel-tested using an Instron tensil testing machine in both the solder-dipped area and the unconditioned area. Exhibit 8 shows all peel test data and failure modes.

All six suppliers are ranked below according to peel strength. It should be noted that test samples of three of the vendors blistered in the solder dip as shown in Exhibit 11. Also, the glass cloth of suppliers D and G separated during peel testing.

Before Solder Dip		After Solder Dip	
1.	B	1.	E
2.	E	2.	F
3.	D	3.	G
4.	A	4.	D
5.	F	5.	B
6.	G	6.	A

Exhibit 11 shows modes of failure (blisters, adhesive failure, and cohesive failure).

3.1.3.17 PLATING OVER A PLASMA TREATED AND CONDITIONED SURFACE. The plated-through-hole shown in Exhibit 10 illustrates the effect of using a gas plasma etch-back treatment and acid sulfate copper plating on polyimide glass laminate. The effect is typical for all six suppliers.

3.1.4 Conclusions

A compilation of all factors used in the selection of the final two suppliers, from which material was ordered, is shown in the supplier comparison chart below.

SUPPLIER COMPARISON CHART

	SUPPLIER AND RANKING					
TEST	A	B	D	E	F	G
Visual	4	2	5	3	1	6
Dimensional	2	1	4	3	2	(5)
1/ Dimensional Stability as	2	(6)	(5)	(4)	3	1
3/ Dimensional Stability	1	(6)	(5)	(4)	(3)	(2)
1/ Peel - Copper Foil As Received	3	1	4	6	2	5
3/ Peel, Copper Foil	4	2	3	6	1	5
2/ Peel, Copper Foil	4	1	2	6	3	5
4/ Peel, Copper Foil	2	3	1	5	(6)	4
Peel, Laminate Exhibit 10	4	1	3	2	5	6
2/ Peel, Laminate Exhibit 10	6	5	4	1	2	3
Cost	5	6	3	4	2	1
Facility Rating	4	5	2	6	3	1

( ) Indicates Failure/Test Requirements
1/ Indicates After Etching
2/ Indicates After Solder Dip
3/ Indicates After Elevated Temperature Exposure
4/ Indicates After Exposure to Plating Solutions

Note: All suppliers except "A" had 2 test failures. The failure of supplier "F" for peel test after exposure to plating solutions is not significant because the solutions used per MIL-P-55617B are not related to any of the processes used in actual fabrication.

Vendor Selection

Two vendors were selected from the six for material procurement for the remainder of the project. Vendor designated by code letter A was selected because they did not fail any of the tests previously described, and all test values were reasonably high with respect to the other vendors. Vendor designated by letter F was selected because of the consistent high values in all categories.

3.2 PROCESS INVESTIGATION

Initially in the program an investigation was made to determine the adequacy of the individual processes used in the state-of-the-art fabrication of rigid-flex cables. In addition, the effects on process variables which would occur as a result of substituting polyimide glass laminate for epoxy glass laminate outer cable stiffeners had to be assessed.

3.2.1 Summary of Work

Each individual process and fabricating step for rigid-flex cable production was examined to determine the areas in which problems were causing low yield. It was determined that the drilling, lamination, drill smear removal, and plating processes were the ones which not only affected yield the most but would be affected by a material change.

A preliminary drilling study was conducted to determine the effects of drill speeds and feeds on the new composite structure incorporating the polyimide glass laminate stiffeners.

Variations in the lamination process were analyzed and such variables as panel border size, press platen pressures, pressure pad arrangement, panel surface treatment, and use of air bleeder channels were investigated.

Variables for the dry gas plasma drill smear removal process were examined by processing and microsectioning test samples of the construction shown in Exhibit 2. During this portion of the program only a small laboratory size plasma reactor was available.

The effects of the copper plating both on the surface and in plated-through-holes were examined from the test panels fabricated in the previously mentioned investigations.

3.2.2 Preliminary Drill Study

3.2.2.1 TEST PANELS. Test panels were fabricated using standard processing techniques. The test panel circuitry configuration was a modified form of the MIL-P-55640 test pattern and is shown in Exhibit 12. The construction of the laminant is shown in Exhibit 2. The panels had no flexible portion, but did represent the SM-2 missile rigid-flex construction.

3.2.2.2 DRILL BITS. The drill bits used in this study were manufactured by the Metal Removal Co. and were identified by style #265. The point configuration was four facet with a 165 degree included angle. The flute helix was 55 degrees.

3.2.2.3 TEST PANEL POST-TREATMENT. Half of the test panels were not processed using the plasma drill smear removal operation and half were prior to plating.

3.2.2.4 DRILLING OPERATIONS. All drilling was performed on a bomb sight drilling machine as depicted in Exhibit 13. The photo and bonding holes were drilled at a speed of 20,000 rpm and a feed rate of approximately 30 in. per minute. The termination holes were drilled at various speeds and feeds in order to achieve an optimum combination that produces smooth, straight-walled, plated-through holes. The effect of each feed/speed combination was determined by plating the hole, cross sectioning it, and observing it at a magnification of from 100X to 500X. Exhibit 14 shows holes which have been drilled at the combinations listed below:

Sample	Speed (rpm)	Approximate Feed Rate (ipm)
1	5,000	20
2	10,000	20
3	20,000	20
4	30,000	20
5	40,000	20
6	5,000	30
7	10,000	30
8	20,000	30
9	30,000	30
10	40,000	30
11	5,000	40
12	10,000	40
13	20,000	40
14	30,000	40
15	40,000	40

3.2.2.5 CONCLUSIONS. The cross sections shown in Exhibit 14 do not depict optimum drilled hole wall profiles, etch-back or smear removal but they do indicate trends. It was noted that after examining all samples which had no post treatment, and had been drilled at 30,000 and 40,000 rpm that gross smear remained on inner circuit layers. It was also noted that at 5,000 and 10,000 rpm more deformation of composite layers was evident. The natural conclusion based on these facts is that a speed of 20,000 rpm should be used as a starting point for drilling. The feed rate of 30 inches per minute was selected from the relative superiority shown in the photomicrographs.

3.2.3 Lamination Analysis

Observations which were made concerning the lamination process for rigid-flex cables have shown that two major yield problems exist. Air entrapment in the laminate and low bond strengths both contribute to delamination and result in the low yields. The work shown below was performed to eliminate the two problems.

3.2.3.1 DETAIL CABLE BORDER MODIFICATION. Each individual printed wiring cable that goes into a rigid-flex cable is processed in the panel form, which may or may not have a copper border surrounding it. The copper border performs two needed functions. First, it increases the x-y dimensional stability of the panel after etching; and second, it allows the panel to be processed through equipment like conveyorized chemical etchers, dryers, strippers, etc., with a minimum of handling damage. The borders also perform an undesirable function in that they act as a dam to prevent air from escaping from between individual layers to be laminated.

Complete Border Removal. Since the borders cause air entrapment in the laminate, a test panel was laminated which had all borders removed from the individual detail cables. A standard pressure and temperature of 600 psi and 370°F respectively, were used for lamination. The outcome of this lamination was that the panel contained no air entrapment, but the registration of laminated circuitry was extremely poor (in excess of 0.020 inch movement). These results precluded the complete removal of copper borders from the rigid-flex detail layers.

Partial Border Removal (Air Bleeder Channels). To prevent air from being trapped by the copper panel borders two different methods of venting were tried. First a series of channels were etched into the copper borders as shown in Exhibit 15. The channels were staggered to allow more even venting and to maintain better dimensional stability. This technique provided no advantage when using standard lamination parameters.

The second method of venting involved mechanically cutting out channels in border areas as shown in Exhibits 16 and 17. A substantial improvement was noted using this technique (when using standard laminating parameters) but air entrapment was not completely eliminated. It was noted, as shown in Exhibit 17 that this technique was sensitive to press platten parallelism.

Conclusion. It was concluded that border modifications did have advantages in removing trapped air from between laminated cable layers but that the previous techniques even if more fully developed would not assure consistent air free lamination.

Since it was apparent that full borders for detail layers are necessary (because of improved registration accuracy), the next determination was to be the optimum border size. A series of test panels were fabricated with 1/2 in., 1 in. and 1-1/2 in. width borders. By comparing corresponding registration accuracy with border width it was concluded that 1-1/2 in. wide borders were needed.

3.2.3.2 INCREASING LAMINATION PRESSURE TO REMOVE TRAPPED AIR. It was believed that the air entrapment could be eliminated by increasing lamination pressures, but it was also recognized that the inner layer circuit registration could be degraded as well. To assess the effects of increased laminated pressure versus registration accuracy a series of panels were laminated using incremental pressures of 400, 500, 600, 700 and 800 psi.

The panels were visually examined after removing the outside copper layers by chemical etching. In addition, circuit registration was measured using radiographic techniques. Exhibit 18 shows the air entrapment in each panel.

Conclusion. As shown in Exhibit 18 all trapped air was removed from the panel laminated at 800 psi. Measurements of the registration of circuit pads indicated that an accuracy better than 0.014 inch (per MIL-P-55640B) had been maintained for all panels. At first these results were very surprising because gross inner circuit movement would usually occur at the higher pressures.

Several weeks after performing this evaluation an additional conclusion was reached. It was discovered that gross misregistration of pad stacks to the intended drilled hole position had occurred. This meant that although individual pad to pad registration was within acceptable limits, gross movement of entire pad stacks had taken place beyond acceptable limits.

The end conclusion concerning the concept of increasing laminating pressures to eliminate trapped air in the laminate is that it is more of a detriment (because of inner circuit misregistration) than an improvement.

3.2.3.3 LAMINATION PRESSURE PAD ARRANGEMENT. After laminating many rigid-flex test panels and observing the occurrence of trapped air within the laminate, it became apparent that the air was naturally located in lower pressure areas as illustrated in Figure 1.

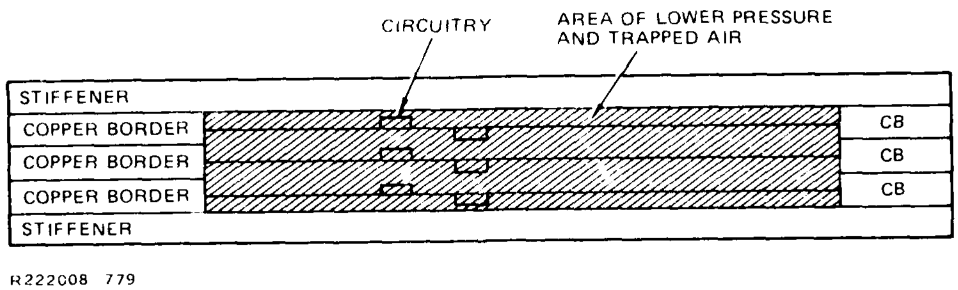


Figure 1. Cross-Section Printed Wire Circuit.

It was also noted that the lower pressure area resulted from an absence of copper in that area (removed during etching).

The techniques, which will be subsequently described, involve the use of a specifically placed pressure pad that equalizes the laminating pressure across the panel as shown in Figure 2.

Pressure Equalization Pads - Stacks of 1 mil Teflon. The first attempt at using this technique was performed after calculating (from Figure 2) that approximately 0.010 inch thick pads were required on each side of the laminate. Ten stacked sheets of 1 mil Teflon were used as a pressure pad on each side of the cable as shown in Figure 2.

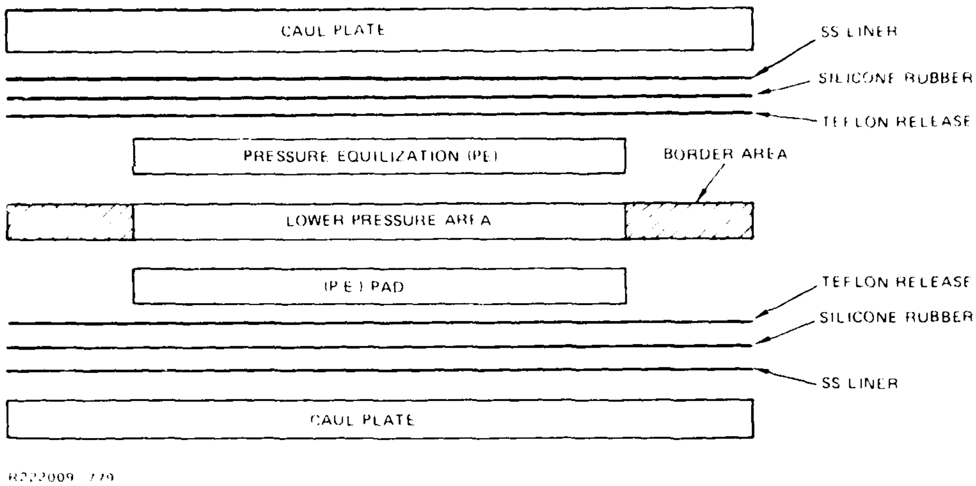


Figure 2. Cross Section of Lamination Tool.

The pad was placed entirely within the borders of all individual detail cables so that it completely covered the laminated rigid portion of the cable. The following standard lamination parameters were used.

1. Platen Pressure - 600 PS
2. Cure Temperature - 370°F
3. Cure Time - 1 hour
4. Post Cure - None
5. Start and Platen Pressure release temperature below 100°F.

Results: The air had been completely removed in the entire area of the cable between the pressure equalizer pads. Traces of trapped air remained in the area outside of the pad location. X-ray examination of the pad to pad registration looked excellent.

Pressure Equalization Pads - 0.031 Unreinforced Silicon Rubber. Because the stacking of 1 mil Teflon sheets is inconvenient and thicker Teflon sheets were not immediately available, a pad of 0.031 thick unreinforced silicone rubber was used as a pressure equalizer pad. The same lamination procedure was used to laminate the test panel as was used for the stacked Teflon.

Results: The laminate contained air entrapment identical to that exhibited for the stacked Teflon pads, however X-ray examination showed that the inner circuitry had moved excessively. It was noted as the lamination tool was disassembled that the silicone rubber pad had distorted to a large extent.

Pressure Equalization Pads - 2 Sheets of 0.005 in. thick Teflon. Two sheets of 0.005-inch-thick Teflon were used on each side of the panel as pressure equalization pads while laminating a panel as described above.

Results: The panel contained no air entrapment except outside of the cable configuration area. Also X-ray examination showed that pad to pad registration was excellent (less than 0.005 inch).

Conclusion. The pressure equalization concept for laminating rigid-flex cables proved to be an excellent technique for producing air-free laminates with a minimum amount of inner circuit movement. This technique was chosen to go into the process development phase of the program.

3.2.4 Increasing Laminate Peel Strength and Bond Uniformity

It had been discovered during early process evaluation phases that the bond integrity of bare Kapton surfaces was very inconsistent. Some Kapton to Kapton bond strengths were low and some high and delamination during processing would occur at times unexplainably.

To produce uniform strong Kapton to Kapton laminations it was decided that a surface treatment was necessary. The best choice of surface treatments seemed to be the dry gas plasma etching process.

An investigation of the effects of an oxygen plasma treatment on the bare Kapton surface was conducted in order to establish optimum process parameters. The test samples were prepared and tested as follows:

1. Kapton insulation sheet was laminated to clean copper-clad Kapton to provide a firm backing.
2. The bare Kapton surface was treated with an oxygen plasma per Exhibit 19.
3. The two treated Kapton sheets were laminated with two sheets of 0.002-in.-thick acrylic film adhesive using a pressure of 400 psi, a cure temperature of 370°F and a cure time of 1 hour.
4. The laminated sheets were cut into 1-inch-wide strips and peel tested on an Instron testing system.
5. The peel strength values are the average of five test coupons.

Conclusions: Bond strengths to a bare Kapton surface are often low but can be improved with an oxygen plasma treatment. The bond strength as shown in Exhibit 19 was improved from an average of 4.4 pounds to in excess of 19 pounds by using a 3-minute oxygen plasma treatment. The 3-minute cycle provides maximum peel strength with a minimum degradation to the Kapton. It has been observed that extended cycle times (in excess of 5 minutes) in an oxygen plasma will degrade the Kapton surface as evidenced by a frosty etched appearance.

3.2.5 Dry Gas Plasma Drill Smear Removal Process

The initial evaluations of the Plasma smear removal process were performed using a laboratory model unit manufactured by International Plasma Corporation. The chamber size was approximately 8 inches in diameter and 13 inches

long, and the R.F. power supply was 500 watts. Panels of the construction shown in Exhibit 2 were processed to determine the etching effect. Exhibit 20 illustrates the effect of a 10 minute cycle using 200 watts of power and 0.5 torr pressure. These results illustrate excellent smear removal and etch-back characteristics. It had been established prior to this contract that this process cycle was adequate for rigid-flex cables constructed with epoxy glass stiffeners. It was, therefore, verified that polyimide and epoxy construction could be processed identically.

The first test panels processed in the production size plasma reactor manufactured by Technics West (shown in Exhibit 21) provided mixed results (good and bad). The reason for the variation in etch-back and smear removal characteristics were attributable to the fact that operating parameters cannot be transposed from one piece of equipment to another. New operating parameters and controls had to be established for the Technics plasma reactor. Exhibit 22 shows the results of two different process cycles; one which has not been affected by the plasma reaction, and one which was substantially etched.

Many rigid-flex panels were processed in the plasma reactor at various time durations and it was found that even panels run at identical cycle parameters showed substantial differences in etch-back amount. It was decided that during the process development phase of this program controls and exact process parameters would have to be established.

Operating parameters for the Technics West Unit, which were established at this time, are listed below:

1. Gases - Oxygen (O_2) and Tetrafluoromethane (CF_4). These gases had been selected and used in previous development programs with success and it was proven that the combination of these gases performed the operation effectively.
2. Gas Mixture Ratio. A previous study which measured the effectiveness of various gas mix ratios in etching acrylic material had established that a 70% oxygen and 30% tetrafluoromethane was close to optimum. Therefore, this ratio was selected as the mixture to be used in this evaluation.
3. Operating Pressure. A total pressure of 0.2 torr was established because higher pressures decrease the plasma uniformity. Note: The laboratory model (I.P.C.) plasma reactor used 0.5 torr pressure as opposed to the 0.2 torr pressure needed for the Techniques unit.
4. Power. A 2000 watt RF power setting was chosen because it provides plasma characteristics needed for the chamber size.
5. Cycle Time. This parameter was chosen as a variable to be used in process development for optimum etching characteristics.

<u>Conclusions</u>: The operating parameters described above can produce effective drill smear removal and etch-back characteristics provided adequate controls are established. The exact process parameters for deliverable hardware were established in the process development phase of this program.

3.2.6 Copper Plating

All panels which were fabricated during the process investigation phase of this program were plated in a Dynachem 240 electroless copper plating bath

and an acid sulfate copper electrolytic plating bath. The plating baths were operated and maintained per the manufacturer's recommendations. All plated test panels were tested for adhesion (tape peel test per MIL-P-55640) and overall plating quality (microsectioned to determine thickness, inner layer continuity and uniformity). In addition, tests such as thermal shock and thermal stress (per MIL-P-55640) were conducted to determine the adequacy of the plating baths used.

Conclusions. The two plating baths mentioned performed with no basic problems and were, therefore, used in the process development phase of this program.

3.3 INITIAL TEST ANALYSIS AND EVALUATION

This phase of the program accomplished two basic tasks. The first task was to test the polyimide glass laminate material ordered from both suppliers "A" and "F" (Para. 3.1) per the requirements specified in Tables 4-1, 4-2, and 4-3 of the contract Statement of Work. The second task was to perform testing on the rigid-flex cables fabricated in Paragraph 3.2.

3.3.1 Summary of Work

3.3.1.1 MATERIAL TESTING. The polyimide glass laminate ordered from both suppliers "A" and "F" were tested per tables 4-1, 4-2, and 4-3 contained in the contract Statement of Work. The laminate was 0.010 inch thick, and clad one side only with one ounce copper.

Tests showed that the copper peel strengths for both suppliers were below the five pound minimum specified in MIL-P-55617 and that the dimensional stability of supplier "A" was unacceptable. Additional material was ordered from suppliers "A" and "F" and retested. After analyzing test results, it was determined that the material ordered from supplier "A" would be used for producing deliverable hardware. All flexible material such as insulation sheet (cover layer), copper clad Kapton, and film adhesive was also tested to pertinent specifications but results will not be reported in this program.

3.3.1.2 RIGID-FLEX CABLE TESTING FOR PARAGRAPH 3.2. Rigid-flex panels fabricated in the process investigation phase of the program were tested for the following characteristics specified in MIL-P-55640.

1. Visual and dimensional
2. Plating adhesion
3. Bond strength (terminal pull)
4. Wrap and twist
5. Hot oil resistance
6. Plated-through hole structure
7. Thermal shock
8. Thermal stress

3.3.2 Testing the Polyimide Glass Laminate

The shipments of polyimide glass laminate received from suppliers "A" and "F" were tested by four (4) different laboratories; Delson Labs, General

Dynamics, Truesdail Labs, and Peabody Testing. The selection of each testing organization was based both on convenience and ability. Each individual test data sheet in Exhibit 23 of the appendix specifies the organization used to perform the corresponding test.

3.3.2.1 NOMENCLATURE OF MATERIAL TO BE TESTED. The material initially ordered from suppliers "A" and "F" was defined by the designation TL GI 0100C1/0A1 per MIL-P-55617B. It was an 0.010-inch-thick polyimide glass laminate, clad one side only with one ounce copper.

The material reordered from suppliers "A" and "F" was defined by the designation TL GI 0100C1/1A1 per MIL-P-55617B. This material was the same as the first ordered except copper cladding was provided on both sides of the laminate.

3.3.2.2 TEST PROCEDURES, REQUIREMENTS AND RESULTS. Exhibits 24 and 25 contain a compilation of all tests performed on the polyimide glass laminate for both suppliers "A" and "F". Included in the compilation are the requirements, controlling test specifications, and summarized test results.

3.3.2.3 INITIAL TEST FAILURES. As can be seen in Exhibits 24 and 25, the single clad material showed failures for the following characteristics:

1. Peel strength
2. Dimensional stability (supplier "A" only)
3. Color-Exhibit (supplier "A" only)
4. Workmanship-Exhibit (supplier "A" only)
5. Surface resistivity
6. Flexural strength (supplier "A" only)
7. Tensile strength.

The surface resistivity failure was resolved by rerunning the test after cleaning the test panels per MIL-P-55617B procedures. It was determined that contamination on the laminate surface, which was probably left by the chemical etchant solutions, caused this failure.

The tensile strength failure we attribute to the difference in the sample thickness used to establish the requirement and that used in our test which was 0.010 inch thick. This characteristic is not considered to be important because the rigid-flex cable is not a prime structural member.

The flexural strength failure was the lowest sample value obtained for supplier "A". The average values did not fall below the minimum spec requirements. This characteristic is also considered unimportant for the same reason stated above.

The failures for peel strength, dimensional stability, and workmanship precluded the use of the single clad material for fabrication. Therefore, a new lot of material was ordered and tested for selected physical properties.

3.3.2.4 RETESTING MATERIAL. Upon receipt of the double clad material from suppliers "A" and "F" another series of tests were run to determine if the material was suitable for use in deliverable hardware. Exhibits 24 and 25 show the tests performed on the double clad polyimide glass laminate.

Conclusions. Based on the results shown in Exhibits 24 and 25 it was concluded that the double clad material ordered from supplier "A" would be suitable for use in the rigid-flex cables to be delivered in this contract.

3.3.3 Rigid Flex Cable Testing for Paragraph 3.2

The rigid flex cables fabricated during the process investigation were tested for the characteristics shown in 3.3.1 per MIL-P-55640. The test panels exhibited no failures for any of the tests or examinations performed.

It was noted that the "plated-through hole structure" examination was very difficult to perform. The test specification, MIL-P-55640 states that all plastic material shall be removed from a plated-through hole and that it shall be visually examined. The specification does not provide a method to accomplish the removal.

After consulting other testing laboratories it was found that fluosulfonic acid is used to remove epoxy from rigid multilayer printed wiring boards, but that there is no accepted method for removing composite materials from rigid-flex cables. As a result several techniques were tried in order to remove the polyimide glass, acrylic, Kapton composite. Three such techniques are listed below:

1. Soaking in a potassium permanganate, sodium hydroxide solution heated to 200°F.
2. Soaking in a chromic acid, trisodium phosphate solution heated to 180°F.
3. Using a dry gas plasma in conjunction with a hydrofluoric acid soak.

Techniques 1 and 2 were moderately successful, with number 3 being the best. The plated hole structure of a test panel was examined using technique number 3 and results were acceptable. Exhibit 26 shows a sample processed using the dry gas/hydrofluoric acid treatment.

Conclusions. The plated-through hole structure examination is difficult to perform and results achieved are dubious when considering that any rejectable attributes might have been caused during the decapsulation process. This examination will not be included in the material test specification generated for this program.

3.4 MATERIAL PROCUREMENT

3.4.1 Flexible Material System

The flexible material used in this program was ordered from E.I. Du Pont de Nemours. An initial order of the following items was procured early in the program and additional quantities were ordered as necessary.

1. Insulation sheet (cover layer) - LF 0210. It consists of 0.001-inch-thick polyimide film (Kapton) which is coated on one side with a film of uncured acrylic adhesive 0.002-inch-thick.
2. Copper Clad Insulation Sheet - 912R. It consists of 0.002-inch-thick polyimide (Kapton) which has one ounce rolled/annealed copper laminated on both sides with acrylic adhesive.

3. Film Adhesive - LF 0200. It consists of a 0.002-inch-thick dry film of uncured acrylic adhesive.

3.4.2 Rigid Material - TL GI 0100C1/0A1 per MIL-P-55617

The rigid material was procured on three separate occasions.

1. Test samples were requested during the material and vendor evaluation from six suppliers.
2. An initial order was placed with suppliers "A" and "F" for eight full-size (36 inch x 48 inch) sheets of material. Two sheets were ordered for testing and six for process development fabrication. This material was single clad.
3. After the material procured on the initial order failed to meet MIL-P-55617B requirements a second lot of material was obtained from suppliers "A" and "F". This material was clad on both sides with one ounce copper (TL GI 0100C1/1A1).

3.5 PROCESS DEVELOPMENT AND FABRICATION

During the process development and fabrication phase of this program it was necessary to manufacture many rigid-flex cables and to measure the effects that variations in individual steps had on the overall process. As cables were built, many shortcomings in the originally conceived fabrication process became evident and it was necessary to modify each process for optimization.

3.5.1 Summary of Work

More than 60 rigid-flex cables of the test pattern configuration were fabricated while varying processing steps. The test pattern rigid-flex cable was used to develop individual processes to be used later in the fabrication of the SM-2 guidance computer cable shown in Exhibit 1. Major improvements were achieved in the laminating, plasma drill smear removal, and copper plating processes while valuable processing information was obtained in the photoengraving and drilling processes.

Six rigid-flex cables of the test pattern configuration and one SM-2 guidance computer cable were fabricated and tested in order to fulfill contract requirements.

3.5.2 Laminating Process

3.5.2.1 VARIATIONS IN PRESS PLATEN PRESSURE. A press platen pressure of 600 psi has been used in production for laminating rigid-flex cables as a standard part of the process. This pressure was used initially in the process development and fabrication phase of the program. More than 30 panels were fabricated using this pressure value in conjunction with the press pad configuration described in Figure 2.

All laminates produced exhibited a clear, air-free structure. In most cases the registration of stacked termination pads was within limits imposed by MIL-P-55640 (0.014 inch). It was discovered, however, that the registration of the termination pad stacks to drilled hole was not consistent. Some holes would actually break out of termination pads as verified by radiographic

(X-ray) techniques. This was an indication that the lamination pressure might be causing the inner circuits and pads to move.

Test panels were laminated at 400 psi and checked for misregistration of individual termination pads and of pads to holes. Registration of the individual pads, and of pads versus holes was acceptable. In addition the laminate was clear and free of trapped air.

To determine how low the laminating pressure could be reduced and still maintain an air-free laminate, test panels were laminated at pressures down to 200 psi. These test panels also exhibited a clear air-free structure.

Conclusions: The clarity of the laminate, which is a function of air entrapment, does not appear to be sensitive to lamination pressure using the concept described in paragraph 3.2.3.3, but retaining registration of inner circuitry and termination pads is. It is apparent that circuit/pad/hole registration can be controlled using lamination pressures below 400 psi, however, experience at the lower pressures is limited. Because of this limitation, 400 psi was selected as a pressure at which to laminate the deliverable rigid-flex cables.

3.5.2.2 VARIATIONS IN LAMINATING TEMPERATURE. The original lamination cure temperature recommended by Du Pont for their acrylic adhesive was 340°F. Recent laminating procedures have been modified to provide a 370°F temperature. The rationale for this increase is that a harder less resilient structure would result because of additional cross-linking of the polymer which in turn would promote cleaner drilled holes. The higher laminating temperature has produced better quality plated-through-holes.

It was believed that even higher laminating temperatures would provide correspondingly better drilling characteristics, so a series of test panels were laminated at 400°F, drilled, plated and evaluated by microsectioning. The results of the microsectioning showed no observable difference in hole quality, but it was noticed that the Kapton in the window area of the cable had degraded. It was thought initially, that the higher temperature may have caused this to happen.

The degradation was such that the Kapton was no longer flexible. If bent, the cable would fracture and flake apart like mica. In addition to the loss of physical properties, the Kapton had darkened in color.

By observing that the cardboard plug, which was placed in the window cutout to equalize pressure, had charred, it was determined that the degradation had been caused by a chemical reaction between the evolved gases (resulting from charring) and the flexible material. This was verified by laminating another panel using a 0.010-inch-thick fiberglass laminate plug. The Kapton exhibited no degradation but it did wrinkle as shown in Exhibit 27.

Conclusions. Cure temperature above 370°F did not provide any added benefits. Therefore, the standard 370°F was used to fabricate all deliverable hardware. Card stock (cardboard paper product) is not suitable as a window plug material.

3.5.2.3 WINDOW PLUG MATERIAL. When it was discovered that the Kapton was made brittle by the cardstock charring during lamination, an effort was made to find a new pressure pad material.

The following materials were tried as window plugs and the corresponding results are shown:

	Window Plug Material	Results
1.	No Plug	Kapton wrinkles in the window
2.	0.010 inch core copper clad polyimide/glass	Kapton wrinkles in the window
3.	0.030 inch unreinforced silicon rubber	Split the polyimide stiffener (Exhibit 27)
4.	0.015 inch core copper clad Teflon/glass	Kapton wrinkled in the window
5.	0.020 inch Nomex 410 (Du Pont)	Good but leaves matt finish
6.	0.013 inch core copper clad polyimide/glass with 2-0.005 inch Teflon inserts (inside)	Excellent results with Kapton clear and unaffected
7.	Same as item 6 except 1-0.005 inch Teflon insert (inside)	Same as item 6, excellent

Exhibit 27 shows typical wrinkles in the window as described above. As a point of interest it should be noted that after trying item 6 above that four rigid-flex cables were laminated using that type of plug. The results were that the outer stiffener material split as shown in Exhibit 27. After analyzing the situation and laminating several other rigid-flex cables it was discovered that new silicone rubber press pads had been used when the split stiffeners occurred. The new rubber pads had tooling pin holes which were oversize (1/2 inch-holes for a number 12 pin size). The rubber could apparently move and cause a stress in the stiffener which in turn caused the crack. To verify that this condition caused the problem four new cables were laminated individually using press pads with the correct size tooling holes. The four cables showed no evidence of cracking and in general looked excellent.

Conclusions: The best window plug material is a piece of polyimide glass laminate (item 6 above) material which is the same as the rigid-flex cable stiffener material. To obtain a smooth, wrinkle-free surface it is necessary to place one or two 0.005-inch-thick sheets of Teflon between cable layers in the window area only. This not only helps to smooth the window area surface, but it also prevents circuit paths from being embossed on adjacent cables.

3.5.2.4 VACUUM LAMINATING. The vacuum laminating process which is a currently established method for fabricating rigid-flex cables was tried on a test pattern rigid-flex cable. The rationale for using this process was that registration of panels laminated using the method shown in paragraph 3.2.3.3 at 600 psi was not acceptable. Since registration achieved in production while fabricating the SM-2 guidance computer rigid-flex cable is acceptable

(but not good) using the vacuum laminating technique it was believed that the pattern rigid-flex would also be laminated equally well.

The process uses a sealed laminating fixture which provides evacuation vents to remove air. An evacuating pressure of -25 inches Hg max is applied prior to press closure. The laminating pressure is 600 psi and the cure temperature is 370°F.

The results of using the vacuum laminating technique on the test pattern rigid-flex were not acceptable. Not only was the registration of pads and circuitry very poor, but the panels also contained large amounts of trapped air.

Conclusions: The vacuum lamination process has been used successfully in the past to laminate the SM-2 guidance computer rigid-flex cable, but it performed unacceptably on the test pattern rigid-flex cable. This indicates that the process is sensitive to part configuration and possibly detailed cable border geometry. Because of this sensitivity the lamination process described in paragraph 3.2.3.3 was pursued more extensively.

3.5.2.5 RELEASE SHEET USED AS A PARTING AGENT. Exhibit 1 shows the placement of the release film as it is used in the laminating process. The film was used originally in this process and other laminating processes as a parting agent between the silicone rubber press pad and the cable.

It was discovered early in the fabrication phase of this program that the 0.001-inch-thick Teflon film performs more than one function. It was found after experiencing a gross delamination problem, that the film acts as a barrier which prevents transfer of silicone oil.

This discovery was made as a result of microsectioning, X-ray, and scanning electron microscope (SEM) analysis. Exhibit 28 shows a cross section of the delaminated area. This identifies the coverlayer surface as the delaminated area.

Further analysis of the delaminated Kapton surface using SEM techniques showed a coating as illustrated in Exhibit 29. The coated and uncoated surfaces were scanned with X-rays as illustrated in Exhibit 30 and it became apparent that the coating contained a substantial amount of silicone.

To substantiate that the coating was silicone oil transferred from press pads, several detail cable laminations were made leaving the silicone rubber in direct contact with the coverlayer. The details were then laminated into a rigid-flex. The resultant cables delaminated as had the ones originally discovered.

It was also confirmed that once used Teflon release film would also transfer silicone oil to the coverlayer and cause delamination.

It should be noted that even the plasma surface treatment which is used on the individual detail cables prior to lamination, cannot remove this silicone oil coating.

Conclusion: A 0.001-inch Teflon release film is required during the lamination of coverlayer to detail cable in order to prevent silicone oil transfer and subsequent rigid-flex delamination. Release films should not be reused because they will transfer silicone oil onto detail cables. Since the silicone oil is not visible normally to the eye and it is not readily removed, every precaution should be taken to prevent the transfer. Care should even be exercised in handling the panels being processed (handle using edges only).

3.5.3 Dry Gas Plasma Drill Smear Removal

3.5.3.1 ESTABLISHING PROCESS SCHEDULE. At the beginning of this program a schedule for processing the rigid-flex cable (for the SM-2 guidance computer) had been established for use in an 8-inch-diameter laboratory Model IPC unit (International Plasma Corp). It was still necessary to develop process parameters for the 38-inch-diameter Technics West production unit.

As a result of the process investigation, it was decided that only one parameter would be varied and that would be time. The cycle time was varied from 10 minutes to 30 minutes in various increments. Exhibit 31 shows the results of various cycle times.

To establish the optimum cycle time for the rigid-flex cable many cables were plasma desmeared, plated cross-sectioned, and analyzed.

3.5.3.2 DETERMINING EFFECTS OF THE HEAT GENERATED BY THE PLASMA. The effects of heat generated by the plasma were noted during establishment of the process schedules. The following effects were observed:

1. The temperature of the plasma chamber rises from ambient as the process cycle proceeds. This will impart a temperature increase in the cable being processed.
2. The longer the process cycle and the more cycles performed (if closely spaced) the higher the chamber temperature will get.
3. As the part and chamber temperature rise, the reaction of the plasma tends to increase, which in turn causes more etchback (material removal) in the drilled hole wall.
4. Temperatures of the cable have reached as high as 400°F during a process cycle (as determined by Tempilaq indicators), which has caused delamination to occur.
5. Delamination of the cables may result even at temperatures down to 200°F if a prebaking operation is not performed prior to processing.

3.5.3.3 REDUCING CABLE TEMPERATURE. A mask, consisting of two aluminum plates which enclose the cable, was developed as part of the smear removal process. The mask as shown in Exhibit 32 has cutouts which allow the cable holes to be exposed. It reduces cable temperature (as a heat sink) and also seems to increase the rate of the gas reaction (reason for this is not apparent).

3.5.3.4 CONTROLLING THE AMOUNT OF ETCHBACK. The two machine variables which were selected for controlling the amount of etchback in holes were cycle time and temperature. It was established that the part should not be cycled until the chamber was cooled to 125°F or below. This prevents a buildup of heat in the chamber which would cause unacceptable variations in etchback uniformity.

3.5.3.5 MONITORING THE PLASMA REACTION. The reaction that takes place in the plasma chamber was monitored using weight loss techniques. Each time the machine was cycled, a sample pre-weighed block of acrylic plastic was suspended in the chamber. After the process cycle, the block was reweighed to determine how much material was etched away. By establishing a range of acceptance for our machine it was determined whether a normal reaction had occurred.

This technique for monitoring process reaction is not precise but is a good indication that the desired results have been obtained.

It must be noted that the weight loss will vary according to the following:

1) Sample surface area
2) Placement of sample in the chamber
3) Test material type (composition)
4) Varies from machine to machine
5) Cycle parameters (pressure, power, gas, time)

A typical weight loss range for the Technics West unit described in M-24-6-879 when operated to the parameters shown below is 300 - 400 milligrams.

Machine operating parameters.

1) Power - 2000 watts
2) Total pressure - 210 torr
3) Gas mixture - 70% oxygen 30% tetrafluoromethane
4) Time - 25 minutes
5) Pump down pressure 10 torr

Conclusions: The establishment of process cycles for plasma smear removal must be performed for each individual part configuration and for each individual plasma reactor system. Process controls should be developed for each individual reactor system based on weight loss and temperature variation techniques described.

3.5.4 Copper Plating

Work performed on the copper plating process involved both electroless and electrolytic baths. The purpose of the work was not only to achieve a copper deposit which meets MIL-P-55640 requirements but would also eliminate a plating void problem which occurs as shown in Exhibit 33. This type of void (if large enough) can cause the plated hole wall to rupture during subsequent soldering operations as shown in Exhibit 34. The plating voids are caused as a result of the inability of the plating process to fill recesses in the drilled hole wall. The recesses are created from either excessive etchback in the plasma smear removal operation or tear-out during drilling.

Filling The Recesses in Drilled Holes

Microsections of test panels which had been copper plated early in the program showed that the primary cause of the voids was that the corners of the recess would close the cavity prior to complete filling or leveling taking place as shown in Figure 3a.

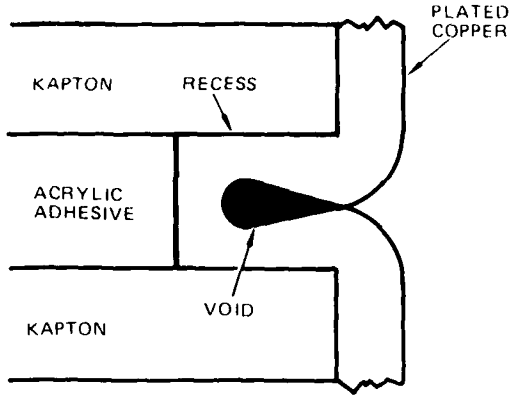


FIGURE 3A

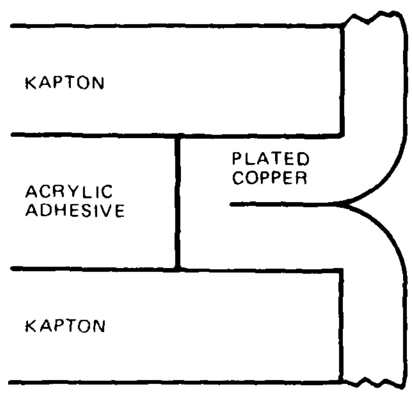


FIGURE 3B

R222036 7/9

It was believed that by filling the recess uniformly as shown in Figure 3b the void would not occur. The three basic approaches for applying a uniform copper deposit were: first the application of thicker electroless copper plating, second the use of pulsed energy electrolytic copper plating, and third the use of a low current density strike followed by a normal plating cycle, which is interrupted about mid-point.

3.5.4.1 THICK ELECTROLESS COPPER PLATING. An investigation was made to find an electroless copper plating bath which would perform the required task of filling plating voids. Several suppliers were contacted and literature of bath performances was obtained.

There are available on the market today many different types of electroless copper baths, all of which are proprietary in composition. Below, an attempt is made at classifying the types, but it is recognized that others do exist.

Type of Bath	Operating Conditions	Thickness of Deposit	Applications
1. Normal Thin Deposit, Standard Production	Room Temp	To 20 µin. in 15-20 min.	General printed wiring, panel and pattern plate
2. High Speed	Room Temp	To 100 µin. in 40 min.	Special printed wiring, panel and pattern plate
3. Heavy-Build	Room Temp	To 400 µin. in 1 hr.	Special printed wiring, panel and pattern plate
4. Heavy-Build	Heated (120°F	UP to 1 oz and more more	All of the above plus additive circuitry

The investigation indicated that a type 2 and 3 bath were the logical candidates for use because type 1 was the standard bath previously used and type 4 offered too many problems related to facilities, control, life, and production loading.

Type 3 Bath

Test panels were processed in a type 3 bath and a plating thickness up to 400 in. was achieved. No voids appeared in the recesses, but the plating did crack and curl away from the laminate as shown in Exhibit 35. This indicated that a thick filling plating might eliminate the voids, but it was not known if the 400 μin. thickness was needed, or if the thickness could be achieved without cracking.

The cracking of the type 3 bath plating was described to the supplier that provided it. Several other panels were processed and the problem could not be resolved. It was concluded that this particular bath could not produce the desired deposit.

The same approach was taken using another bath supplier, but his bath could not achieve a thick enough deposit (less than 200 μin.).

It was concluded after contacting several electroless copper suppliers that there was not a type 3 bath which would perform adequately.

Type 2 Bath

Since the deposit thickness required to eliminate the plating voids was not known, a type 2 bath was evaluated. The bath was operated initially at standard makeup composition and a 100 μin. deposit was achieved. This provided an improvement over a standard bath, but it did not completely eliminate the voids.

The type 2 bath was next modified (according to the supplier's recommendations) to achieve maximum performance. The modification involved lowering the hyproxide concentration level, which made the bath life unstable, but since it was for a single usage that did not matter. The results of test panels processed in this type 2 bath are shown in Exhibit 36. Note that three immersion times were used and that a 200 μin. thickness was reached. None of the samples exhibited plating voids but the amount of etchback is substantially less (500-800 μin. versus almost 1700 μin. for the voided sample).

Type 4 Bath

Even though it was decided that a type 4 bath would not be used in this program, a test panel was processed in the bath out of curiosity. Exhibit 37 shows the results. Surprisingly, it did not achieve the desired thickness for the time processed (250 μin. for 2 hours). Microsections of this panel indicated that a 250 μin. thickness would also not eliminate the void problem.

3.5.4.2 PULSED ENERGY ELECTROLYTIC COPPER PLATING

Establishment of Operating Parameters. A Nova-tran pulse plating rectifier was supplied for evaluation and a series of test panels were processed. The first panels were 0.062-inch-thick, double-clad epoxy glass laminate, which contained a series of 0.032-inch-dia. holes, which were etched-back using dry gas plasma. These panels were processed as follows:

1. Electroless copper plated (DynaChem 240)
2. Pulse plated in an acid copper sulfate plating bath (Sel-Rex Q Bath) at 5%, 9%, 17%, 23%, 33%, and 50% duty cycles

   Example 50% duty cycle = 50 Milliseconds on
   50 Milliseconds off

3. Microsectioned and examined for plating thickness versus time, crystal structure, and filling characteristics.

Plated-through-holes in the panel showed excellent filling characteristics. The copper grain structure was coarse for panels plated at duty cycles less than 33%, but fine for those above.

This set of panels was used only to establish starting parameters for rigid-flex cable processing.

Pulse Plating A Rigid-Flex Cable

Several rigid-flex test panels were plated and examined as described above, but only duty cycles of 33%, 50%, and 65% were used. Duty cycles of 33% and above were selected because of the accompanying fine, copper grain structure.

No major difference in the copper deposit was noted using 33%, 50%, or 65% duty cycles. Some panels exhibited copper voids and some did not for all 3 cycles. Control panels were also processed using direct current (dc) energy. The dc plated panels showed the same mixed results.

3.5.4.3 LOW CURRENT DENSITY STRIKE WITH AN INTERRUPTED NORMAL CYCLE. Prior to and after the evaluations performed in 3.5.4.1 and 3.5.4.2 another method for reducing copper plating voids was being evaluated on every test panel being processed. It was a cycle similar to that shown below.

	Operation	Time	Solution
1.	Plate at 1/2 current density	10 min	Acid sulfate copper
2.	Plate at full current density	30 min	Acid sulfate copper
3.	Remove panel and rinse	60 sec	Running tap water
4.	Immerse in sulfuric acid	60 sec	20% H_2SO_4 by concentration
5.	Plate at full current density	60 min	Acid sulfate copper

This kind of plating interruption has reduced the frequency of copper voiding significantly. The low current density strike reduces buildup of copper plating at recess edges and the interruption tends to knit the plating surface together thus eliminating some voids and seams in the copper.

Conclusions: None of the three methods for eliminating plating voids in the copper hole wall were completely successful. The thick electroless copper and the low current density strike (followed by an interruption in the normal cycle) seemed to reduce the frequency of voiding but did not eliminate it.

Observations of the microsections taken during this study indicate that the depth and shape of the recess mainly determine if a void in the plating will form. Voids usually form in narrow (<0.0015 inch) deep recesses (>0.0015 inch) which are closing toward the entrance (Exhibit 38). Voids usually do not form in wide (>0.002 inch) shallow (<0.001 inch) recesses.

These observations have led to a reduction in the amount of etchback during plasma desmearing of holes.

3.5.5 Photo Engraving and Etching

3.5.5.1 ETCHING COPPER CIRCUITRY. During this program four chemical etchants have been used to remove the copper between circuits, termination pads and other conductive features on rigid and flexible cables. These etchant systems are listed below.

1. Chromic Sulfuric
2. Ferric Chloride
3. Cupric Chloride
4. Ammoniacal

They all perform acceptably when etching clean copper, but if the oxide which is produced by the laminator is left on the panel, the ammoniacal etchant performs unacceptably. This was discovered while removing the 1-ounce copper from the double clad polyimide stiffener material.

3.5.5.2 STRIPPING PHOTO RESIST. Three different photo resist strippers were evaluated to determine their effectiveness, and compatibility with rigid-flex composite materials.

Riston 1100X Stripper

This was the prime stripper to be used for process development. The stripper is supplied by Du Pont as part of a system for processing Riston 218R dry film photo resist. It removes the resist in about 3 to 5 minutes and is a heated aqueous system. It is compatible with the acrylic adhesive system but does cause some temporary swelling. After drying the stripped part in an oven the swelling disappears and provided the correct minimum strip time is used no residue remains on the cable after stripping.

3.5.6 Z-Axis Thermal Expansion Study

Initially in this development program it was decided that the thermal expansion characteristics of the acrylic adhesive (currently used to fabricate rigid-flex cables) should be compared to those of the previously used phenolic butyral adhesive and a possibly better polyimide adhesive. This information was needed to augment data previously obtained for the polyimide glass. Thermal mechanical analysis techniques (TMA) were used by Delsen Labs to obtain this information.

The samples for testing consisted of prelaminated sheets of adhesive film using constant temperatures and pressures for all laminations. The adhesive films were supplied as follows:

1. Acrylic adhesive — E.I. Du Pont de Nemours
2. Phenolic butyral adhesive — Rexham Co.
3. Polyimide — Rhodia Co.

The tests were performed on the laminated material using two thermal cycles and yielded some very interesting information. It was noted that all three materials took on a permanent expansion (set) after the first cycle.

Shown below are the amounts of permanent set exhibited as well as the corresponding coefficients of thermal expansion.

Material	Permanent Set (Mils)	Thicknesses (Percent)	Coefficient of Thermal Expansion (μ in./°C)	Tg (°F)
Acrylic	12	12	302	196
Phenolic butyral	3	5	472	325
Polyimide	7	11	45.5	252

The curves from which this information was obtained are shown in Exhibit 39. It should be noted that the coefficient of thermal expansion for the first cycle of the polyimide was 638 μin./°C. This indicated that a post lamination cure for the polyimide is mandatory to relieve stresses prior to drilling and plating through holes. It was also believed that a post lamination cure cycle would offer advantages to the acrylic adhesive as well.

The accepted fact that Z-axis expansion can be great enough to rupture plating in plated-through-holes during thermal stress, and the information discussed above prompted a TMA study on a fully laminated rigid-flex cable. It was believed that a post lamination cure could artificially remove some of the Z-axis thermal expansion under controlled conditions. The plan, as described below, was intended to establish the lowest possible temperature at which to achieve the maximum amount of permanent set prior to drilling and plating. Table 1 shows the preconditioning and temperature cycles. The vacuum bake preconditioning was used to remove the water expansion variable.

Exhibit 40 shows all TMA curves for the rigid-flex above. A reverse phenomenon took place on each of the samples. Instead of a permanent set in the expansion mode, a permanent set in the contraction mode took place after the first cycle. These results were entirely unexpected and are unexplainable at this time. The results showed a shrinkage of less than a mil for all eight samples taken. The coefficients of expansion ranged from 123 to 293. These results indicate no need for a post lamination cure as a stress relief.

Two additional curves were run at temperatures approaching that used for soldering (500°F). These curves indicate the same reaction previously described taking place and are shown in Exhibit 41.

Table 1

Sample	Precondition	1st Cycle (°F)	2nd Cycle (°F)
1	165°F bake in a vacuum of 25 inch Hg	200	350
2	165°F bake in a vacuum of 25 inch Hg	250	350
3	165°F bake in a vacuum of 25 inch Hg	300	350
4	165°F bake in a vacuum of 25 inch Hg	350	350
5	No preconditioning	200	350
6	No preconditioning	250	350
7	No preconditioning	300	350
8	No preconditioning	350	350

The last part of this thermal expansion study was the most interesting. A relative comparison of the thermal expansion characteristics of a rigid-flex cable built using polyimide-glass stiffeners was made with one built with epoxy-glass stiffeners. Exhibit 42 shows the thermal expansion curves for both cables. The expansion of the cable in the Z-axis with epoxy glass stiffeners was 4.125 mils while the one with the polyimide glass stiffeners was 1.9 mils. The overall thickness of the cable with polyimide was 73 mils while that of the one with epoxy was 74 mils.

Methyl Ethyl Ketone (M.E.K.)

This solvent strips the Riston 218R in about 45 to 60 seconds and leaves no residue provided a double immersion system is used. No noticeable attack is apparent on the acrylic adhesive or Kapton providing reasonable immersion times are used (less than 2-1/2 minutes).

Strongly Alkaline Strippers

Strippers which are strongly alkaline should not be used. Exhibit 43 shows severe delamination in the coverlayer which was laminated to a flexible detail cable. A cross section (Exhibit 44) proved that the stripper had lifted the acrylic adhesive from the base Kapton.

3.5.7 Fabrication of Rigid-Flex Cables

The basic process for fabricating rigid-flex cables is shown in Process Specification M-24-6-876. The specification contains a process flow diagram which shows each major process step and the sequence in which the composite materials go together. This basic process approach was used to fabricate all cables for individual process development, product testing, and contract delivery.

The six cables of the simple configuration (test pattern rigid-flex) and the one cable of the SM-2 missile design (P/N 3217116) were fabricated to the above mentioned process specification.

3.6 TEST AND EVALUATION

As the process development and fabrication phase of this program proceeded, the effectiveness of each individual process was determined by examining and testing the cables produced. When it was established that all processes were developed sufficiently to produce cables which would meet the Standard Missile (SM-2) requirements, the deliverable hardware was fabricated and tested.

Test Requirements and Procedures

Since there is no recognized government or military specification which defines the requirements and test procedures for rigid-flex printed wiring cables, it was the intent of this program to establish and document such a specification. Three specifications were used as a source from which to draw and are listed below:

1. MIL-P-55640A Printed Wiring Boards Multilayer (Plated-Through-Hole)
2. MIL-P-50884 Printed Wiring, Flexible
3. MIS 23456 Printed Cable, Flexible (General Specification For)

The MIL-P-55640A specification was the primary source for requirements and test procedures performed during this contract.

In-Process Nonconformances

During the Process Development Phase of this program all cables produced did not receive the entire MI-P-55640A requirement inspection. Instead each unit was tested and inspected for attributes which applied to the indenture level of processing being evaluated. The following list of non-conformance were observed.

1. Brittle Kapton The flexible portion of a series of rigid-flex cable (test pattern configuration) was found to be so brittle that they broke and fractured when bent. The cause is shown in 3.5.2.2.
2. Separation of Inner Circuit From Plated-Through Hole The inner circuits on one rigid-flex test panel showed separation from the plated-through hole. The cause of the separation was traced back to a 5-minute immersion time in the cleaner conditioner on the electroless copper plating line. The excessive time had caused the adhesive to extrude out over the inner circuit layer as shown in Exhibit 45.
3. Delamination of rigid-flex layers - References 3.5.2.5 and 3.5.5.2.
4. Plating voids - Reference 3.5.4
5. Thermal stress - One panel exhibited a crack in the plated-through hole wall during the thermal stress test. Expansion of the cable in the Z-axis had caused the crack, but it could not be proven that the plating bath was out of control. Several test panels subsequently plated and thermal stress tested did not evidence cracking, and tensile/elongation values were within acceptable limits (10% min).
6. Trapped air in the laminate. The only panel exhibiting trapped air was that produced using vacuum lamination techniques (3.5.2.4).

Testing Deliverable Rigid-Flex Cables

Exhibit 46 presents the inspection and testing program performed on the deliverable rigid-flex cables. The cables conformed to all requirements, except it was noted that a halo was found on the connector fastener hole of the SM-2 cable. This type of defect was considered to be cosmetic only. The defect occurred as a result of a severe reaming operation in which a 3/16-in. diameter hole is opened up to 0.300 in. diameter. The technique used for reaming the hole involved entering the hole from one side only. To eliminate this condition a different technique, using an entry from both sides, was investigated. The double entry did help, but did not eliminate the defect as shown in Exhibit 47.

SECTION 4 SUMMARY OF PROGRAM ACHIEVEMENTS

4.1 COST AND YIELD IMPROVEMENT

The average cost for producing an SM-2 guidance computer (P/N 3217116) rigid-flex cable is currently approximately $510 per unit when calculated from an average yield of 60% . The 60% yield is an average figure based on the current production process and epoxy glass stiffener construction.

The projected yield resulting from improvements derived from this development program is 85% and as can be seen in Exhibit 48 the projected cost will be $360 per unit.

4.2 INNOVATIONS PROVIDING COST REDUCTION

4.2.1 Z-Axis Expansion Reduction

Cracking of copper plating in plated-through holes will be minimized by a substantial reduction in Z-Axis thermal expansion. As shown in 3.5.6, the difference in Z-axis expansion between rigid-flex units constructed of polyimide glass laminate stiffeners and epoxy glass laminate stiffeners was 54% (4.125 mils for an epoxy unit and 1.9 mils for a polyimide unit).

4.2.2 Improved Drilling Characteristics

4.2.2.1 The polyimide glass laminate will drill cleanly and produce no drill smear. Epoxy smear is prevented by elimination.

4.2.2.2 Drilled hole profiles are straight because the adhesive is not torn out.

4.2.2.3 Drill speed and feed parameter ranges are wider with polyimide glass laminate construction.

Polyimide Glass Laminate	Epoxy Glass Laminate
Speed - 15000 - 25000 rpm	15000 rpm
Feed - 20 - 30 ipm	20 ipm
Rate - 00133 - 0014 in/Rev	.00133 in/Rev.

Note: Drill sizes 0.018 - 0.125 in. Dia.

4.2.3 Elimination of Circuit Tilting and Separation

Exhibit 49 shows a rigid-flex (P/N 3217116) cable constructed with epoxy glass laminate stiffeners and Exhibit 50 shows the same cable configuration constructed with polyimide glass laminate stiffeners. The laminate and circuit tilting in Exhibit 49 occurs frequently in current production when tested by soldering a terminal pin into a plate-through connector hole. This cable and all cables fabricated with it are scrapped because of evidence of inner circuit separation.

Exhibit 50 is typical of the polyimide construction and to date the tilting and separation problem has not been encountered. It is believed that the combination of an improved lamination technique and the polyimide construction have accounted for this improvement.

4.2.4 Process Compatibility

The polyimide construction has provided excellent processing uniformity because chemical solutions and gas plasmas react the same on the flexible Kapton layers as they do on the polyimide glass laminate.

4.2.5 Improved High Temperature Properties

The polyimide construction will withstand all temperature variations required of a rigid-flex cable without degradation. Soldering, baking, or thermal cycling requirements have not caused the cable to fail in any respect.

4.3 DOCUMENTATION

All specifications necessary to fabricate rigid-flex cables have been written and are listed below.

4.3.1 Material Specifications (Exhibit 51)

	TITLE	NUMBER
a.	POLYIMIDE INSULATION SHEET	MIS 23660
b.	ADHESIVE FILM	MIS 23661
c.	COPPER CLAD INSULATION SHEET	MIS 23659
d.	THIN CLAD POLYIMIDE GLASS LAMINATE	M-24-6-874

4.3.2 Product Specification (Exhibit 52)

a.	RIGID-FLEX PRINTED WIRING CABLES	M-24-6-875
b.	PRINTED CABLE ASSY, FLEXIBLE, GUIDANCE COMPUTER	3217116

4.3.3 Process Specifications (Exhibit 53)

a.	GENERAL PROCESS FOR FABRICATION RIGID-FLEX PRINTED WIRING CABLES	M-24-6-876
b.	COPPER PLATING RIGID-FLEX PRINTED CABLES	M-24-6-877
c.	IMMERSION TIN PLATING RIGID-FLEX PRINTED WIRING CABLES	M-24-6-885
d.	LAMINATING RIGID-FLEX PRINTED WIRING CABLES	M-24-6-883
e.	DRY GAS PLASMA DRILL SMEAR REMOVAL	M-24-6-879
f.	PHOTO ENGRAVING AND ETCHING RIGID-FLEX PRINTED WIRING CABLES	M-24-6-880

4.4 DELIVERABLE RIGID-FLEX PRINTED WIRING CABLES

4.4.1 Six each of the test pattern configuration rigid-flex cables were fabricated and tested per contractual requirements. These units were delivered to NOSC in San Diego, California.

4.4.2 One each of the SM-2 Guidance Computer rigid-flex cable configuration (P/N 3217116) was also fabricated and tested to contractual requirements. This unit was delivered to NOSC in San Diego, California.

SECTION 5 RECOMMENDATIONS

Substituting polyimide glass laminate for epoxy glass laminate as cable stiffeners in rigid-flex printed wiring cables has many advantages as shown in this report. The substitution should be performed to improve production yields. In addition, the processing techniques described in Exhibit 53 should be incorporated to augment those benefits derived from the polyimide constructions.

METRIC CONVERSION TABLE

ENGLISH OR U.S. CUSTOMARY UNIT	METRIC (SI) UNITS TO	CONVERSION FACTOR MULTIPLY BY
LENGTH		
INCH	METRE (m)	2.540 000 E-02
MIL	METRE (m)	2.540 000 E-05
MICRO INCH	METRE (m)	2.540 000 E-08
FOOT	METRE (m)	3.048 000 E-01
AREA		
INCH SQUARED (in^2)	METRE SQUARED (m^2)	6.451 600 E-04
FOOT SQUARE (Ft^2)	METRE SQUARED (m^2)	9.290 304 E-02
VOLUME		
INCH, CUBIC (IN^3)	$METRE^3$ (m^3)	1.638 706 E-05
FOOT, CUBIC (Ft^3)	$METRE^3$ (m^3)	2.831 685 E-02
FORCE		
POUND (lb)	NEWTON (n)	4.448
OUNCE (AVOIRDUPOIS)	KILOGRAM (kg)	2.834 952 E-02
PRESSURE		
Lb t/in^2 (psi)	PASCAL (Pa)	6,894 757 E+03
MILLIMETER OF MERCURY (0°C)	PASCAL (Pa)	1.333 22 E+02
TEMPERATURE		
DEGREE FAHRENHEIT (°F)	DEGREE CELSIUS (°C)	t_C-(t_{of}-32)/1.8
THERMAL CONDUCTIVITY		
BTU in/$hr^2 ft^2$ °F	CAL-cm/SEC-CM^2.°C	2,923 E+03

NOTE: (1) E.... Designates exponent of 10

(2) Source of units - ASTM E 380-76e

(3) Even though pressure conversion is designated at 0°C it can be used to provide accuracy needed.

EXHIBITS

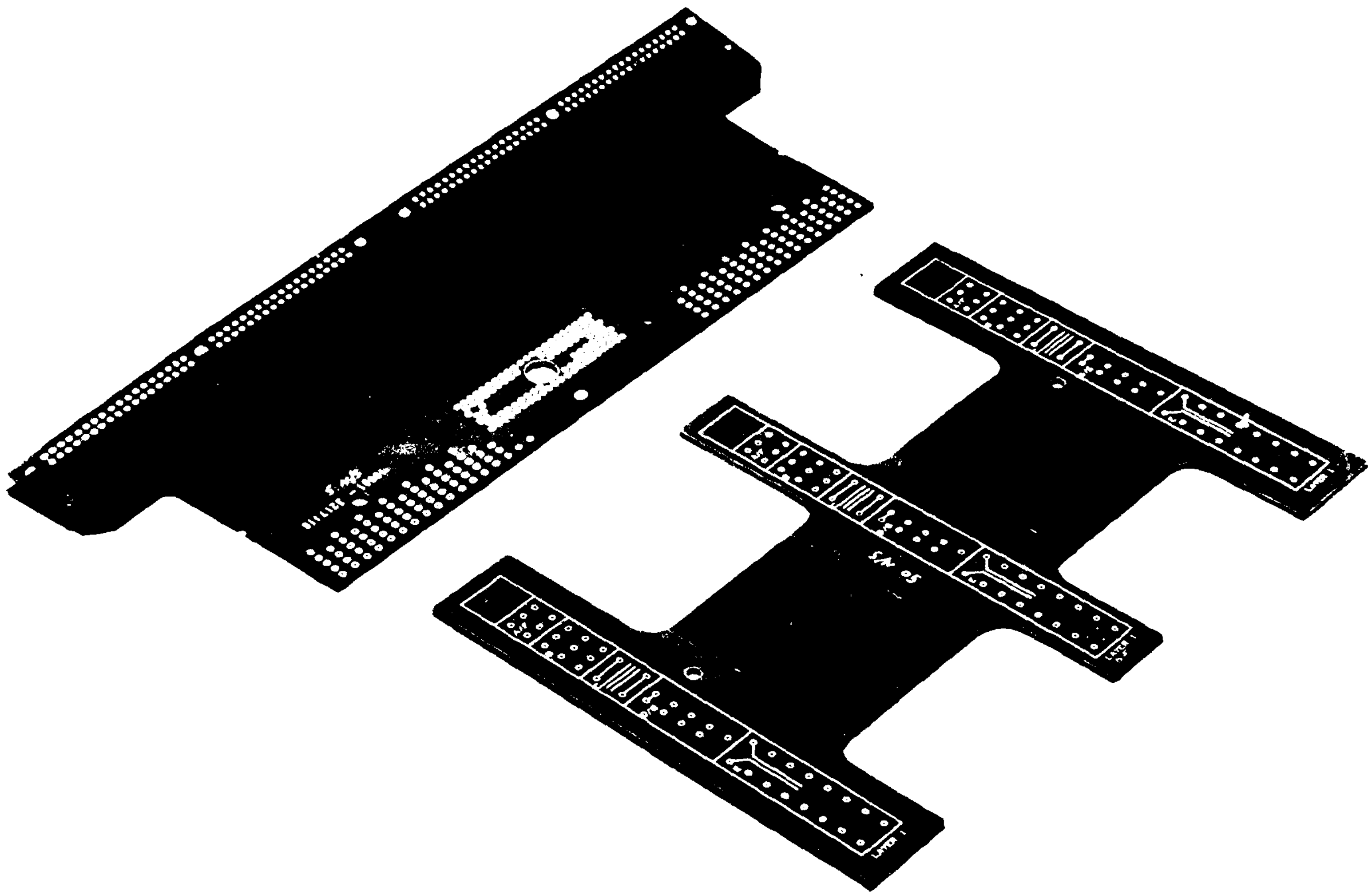


EXHIBIT 1. Deliverable Rigid-Flex Cables of Polyimide Construction.

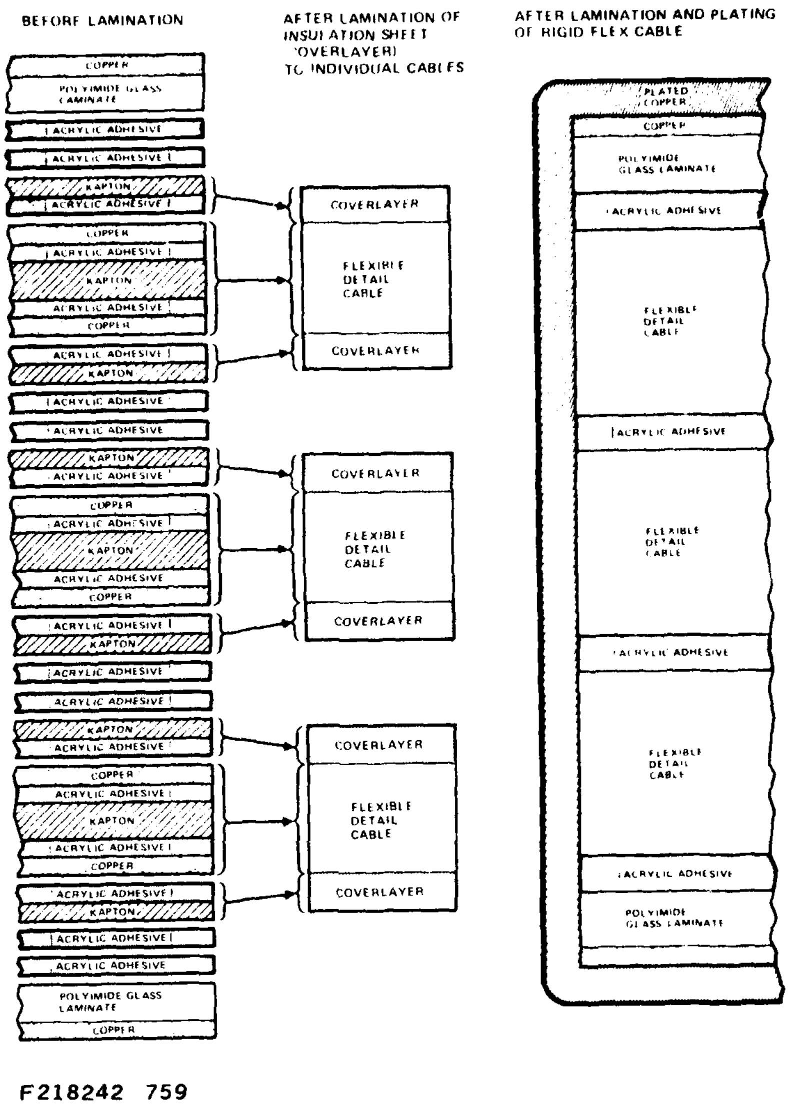


EXHIBIT 2. Rigid-Flex Cable Construction

EXHIBIT 3
TEST PLAN

RIGID FLEX PRINTED CIRCUIT MANUFACTURING PROCESS

CDRL A001
CODE IDENT 99584
M-24-6-689

OCTOBER 1977

A MANUFACTURING TECHNOLOGY PROGRAM
DEVELOPED FOR
THE NAVAL OCEAN SYSTEM CENTER
SAN DIEGO, CALIFORNIA 92152
UNDER CONTRACT N00123-77-C-1192

Test Plan

NOSC
Naval Ocean Systems Center San Diego, California

Cleared for Public Release Distribution Unlimited

GENERAL DYNAMICS
Pomona Division
P.O. Box 2507, Pomona, California 91766

PERFORMED FOR THE

NAVAL OCEANS SYSTEM CENTER

BY

THE ADVANCED MANUFACTURING TECHNOLOGY GROUP

UNDER CONTRACT N00123-77-C-1192

FOR ADDITIONAL COPIES CONTACT:
NAVAL OCEAN SYSTEM CENTER
271 CATALINA BLVD.
SAN DIEGO, CA, 92152
MF CODE 748 (C. SPURLIN)

GENERAL DYNAMICS
Pomona Division

79252 7117

FORWARD AND APPROVAL SHEET

This report is the first document submitted to the Naval Ocean Systems Center in San Diego, California under Contract N00123-77-C-1192, 30 days from the date of contract issuance. It contains the test plan as specified in the Statement of Work (SOW) shown in the subject contract. All labor, material, and services have been supplied by General Dynamics Pomona Division under the direction of Dr. Marvin Abrams and under the coordination of R. W. Aubert. The principle investigator in the project is J. A. Reavill.

The report content has been presented to and approved by C. Spurlin, the Naval Ocean Systems Center Project Monitor.

Marvin Abrams

Dr. Marvin Abrams

R. W. Aubert

R. W. Aubert

J. A. Reavill

TEST PLAN FOR THE NAVAL OCEAN
SYSTEMS CENTER (NOSC)

1.0 INTRODUCTION

1.1 PURPOSE: This test plan is written to describe and provide details of the activities which will be performed under Contract N00123-77-C-1192. A time schedule by which all activities will be performed is also included.

1.2 SCOPE: Eleven activities will be described and the schedule for the completion of each activity will be shown on a bar chart. The Eleven activities to be accomplished within a 14 months time span are 1) Test Plan, 2) Material and Vendor Evaluation, 3) Process Investigation, 4) Initial Test Analysis and Evaluation, 5) Material Procurement, 6) Fabrication and Process Development, 7) Test and Evaluation, 8) Yield and Cost Analysis, 9) Preparation and Submission of Reports, 10) Program Debriefing, and 11) Deliverables.

2.0 ACTIVITY DESCRIPTION

2.1 Test Plan - Described in this report.

2.2 Material and Vendor Evaluation.

2.2.1 At present there are Eight (8) possible vendor candidates to evaluate. Listed below are the companies which manufacture polyimide-glass laminate material.

1. Dupont De Nemours
   21444 Golden Triangle Rd.
   Saugus, CA 91350

2. Young Blood Laminates
   P.O. Box 319
   Millbury, MA 01527

3. Synthane Taylor Laminates
   1400 Arrow Highway
   La Verne, CA 91750

4. Mica-Ply Laminates
   10900 Washington Blvd.
   Culver City, CA 90230

5. Norplex Laminates
   1300 Norplex Dr.
   La Crosse, WI

6. Fortin Laminates
   1323 Truman St.
   San Fernando, CA 91340

7. Howe Industries
   13704 Satacoy Street
   Panarama City, CA

8. Atlantic Laminates
   New Hampshire

2.2.2 The evaluation of these suppliers and corresponding materials will be performed as follows:

1. Each vendor will be contacted either by mail or telephone to determine if his laminate material is suitable for manufacturing rigid flex printed wiring cables (thickness, copper weight and grade, glass cloth weave style, and polyimide resin).

2. A plant survey will be performed at each applicable vendor's facility, to determine their manufacturing capability, quality level, and willingness to participate.

3. Samples of material will be obtained from those qualified vendors desiring to participate in the program and selected tests will be performed in order to establish the usability of each vendors material. The tests and corresponding requirements selected will come from the following possible sources: Institute of Printed Circuits (I. P. C.) Methods, American Society for Testing Materials (A. S. T. M.) Methods, MIL-P-55617, MIL-STD-202, MIL-E-5272, MIL-STD-2026, Underwriters Laboratories (UL) 94 and General Dynamics Testing Procedures.

4. A preliminary evaluation of the test results will be performed to select the 3 material suppliers which appear to be able to meet contract requirements best. Material from these 3 suppliers will be tested per Table 4-1, 4-2, and 4-3 of the SOW of the contract documentation in order to arrive at the one final material to be used throughout this evaluation.

3.0 PROCESS INVESTIGATION

The major process steps used to fabricate rigid flex printed wiring cables are: drilling, plating, laminating, drilled hole smear removal, photo engraving, and circuit trace etching. Variations in processing techniques will be investigated to select the best possible combination in order to produce SM-2 rigid-flex cable configurations at an overall 85% yield acceptance.

3.1 DRILLING

3.1.1 Drill feeds and speeds will be varied on simulated harness test patterns. Drilled hole quality will be measured by cross sectioning the plated through hole and inspecting under 100X min. magnification.

3.1.2 Drill point geometry will also be varied on simulated harness test patterns. Hole quality will be determined per paragraph 3.1.1.

3.1.3 The effects of various back-up and entry material will be established and hole quality will be determined per paragraph 3.1.1.

3.2 COPPER PLATING

Copper plating will be investigated as two specific processes, electroless copper and electrolytic copper.

3.2.1 Electroless Copper Plating

Since there are no less than 20 different electroless copper baths on the market today, it is not possible to try all of the baths in this evaluation. However, at least 3 different baths will be used to demonstrate that the rigid flex cable fabrication is not limited to a single suppliers product line. No attempt will be made in this evaluation to select or name the best electroless copper bath or to specify the optimum bath operating conditions. Instead, it will only be shown that a given suppliers product will perform adequately as a newly made bath. Records will be kept of the baths performance and operation, but this will only be reported on a summary basis. From the following list of suppliers, 3 baths will be chosen for use which exhibit adequate coverage, adhesion and deposition rates:

1. Shipley
2. McDermid
3. Dyna Chem
4. Hatch
5. Enthone

3.2.2 Electrolytic Copper Plating

The principle electrolytic copper plating baths used in the printed wiring industry today are pyrophosphate copper, and sulfate acid copper. Both of these baths will be used in the evaluation and one will be selected for use on the deliverable hardware. The one to be selected will meet the requirements of MIL-P-55640 from which the following paragraphs will be satisified: 3.4, 3.4.2, 3.6.3, 3.7, 3.11, 3.19, with only those exceptions specified in SM-2 missile design requirements. These exceptions do exceed MIL-P-55640 requirements.

3.3 DRILL SMEAR REMOVAL

The removal of organic material from inner circuits of multilayer circuit boards and harnesses has been accomplished in a variety of ways using wet chemicals or dry gases. Wet chemical processes use extremely corrosive chemicals such as chromic acid, hydrofloric acid, concentrated sulfuric acid, and fluosulfonic acid. The wet chemical processes will not be used as a method for drill smear removal in this evaluation because of the danger to personnel and because of the difficulty in waste disposal. Instead, a process developed at General Dynamics using a dry gas plasma will be used to remove drill smear. This process will perform the smear removal operation cheaper and more efficient than wet chemical processing.

The process working parameters will be established for the coupons processed in this evaluation and also for the deliverable hardware. This process will be performed on all coupons and deliverable hardware with the exception of some of the first samples used to establish drilling techniques.

Variations in amount of etch-back produced by the plasma will be studied to establish an acceptable hole wall profile.

3.4 PHOTO ENGRAVING

The resolution of line widths is dependent on many parameters. The primary factor in achieving fine line resolution is the photo tool. Throughout the program a silver-halide glass photo tool will be used to print circuit patterns on inner circuit layers and a 0.007-inch thick silver-halide film will be used on outer layers. This is the best combination to be used for good quality.

Secondary, to the photo tool is the type of photo resist to be used. Two of the major aqueous dry film photo resist suppliers will be evaluated, Dyna Chem, and DuPont.

In addition, adhesion of photo resist to the substrate is important in achieving fine line resolution. The adhesion of the resist to the copper can be improved by better surface preparation and increasing pressure on dry film laminator rolls. In this evaluation several copper cleaners will be used to clean the copper clad base material. The increased photo resist adhesion will be determined by the amount of touch up necessary and also by the resist edge sharpness. Additional pressure to the dry film resist rollers will be applied in this evaluation to achieve better adhesion.

3.5 ETCHING

Etching copper circuitry can be achieved in a variety of chemical solutions. The reasons for using each chemical solution vary from user to user and can be summarized as follows:

1. Lowering costs
2. Achieving good ecological balance (re-use of solution or easy disposal)
3. Achieving straight circuit side walls
4. Preventing chemical attack on base materials or plating
5. Regenerating or rejuvenating ability of system
6. Providing a constant etch rate

The etchant solutions to be used in this evaluation will be an ammonical system and a regenerative cupric chloride system. These two systems will be used by standard supplier recommended operating procedures. This will allow any contractor to achieve good results using "off the shelf items."

4.0 INITIAL TEST ANALYSIS AND EVALUATION

4.1 TEST SAMPLES

Tests will be performed in the process investigation (Item 3) on test panels which will simulate the SM-2 missile rigid-flex cable complexity and design. However, the first test coupons will be simple and will consist of only stacked layers of copper laminated in the same construction as the SM-2 hybrid. These coupons will not contain inner circuit layers or termination pads and will serve only to accumulate basic data for plating integrity and bond strengths.

The more complex test pattern will resemble the design shown in Figure 1h of MIL-P-55640, however, pad size and circuit line width will be 0.060 and 0.010 respectively. The number of circuit layers will be Eight (8), which is the same as the most complex SM-2 missile harness. All of the pad stack-ups will not have Eight (8) conductor layers so that the SM-2 missile design can be correctly simulated.

The above test samples can be used for drilling, plating, plasma de-smearing, etching and photo engraving, but because of the complexity of laminating, an actual SM-2 harness design will be used as a test panel.

4.2 DRILLING

Drilling will be performed on two sided harnesses and on multilayer construction. Very little emphasis will be given to two sided drilling, however, and most of the effort will be concentrated on multilayer construction.

4.3 TESTING FACILITIES

The material testing laboratory at General Dynamics Pomona Division will be used for all routine testing of base materials and composite structures. Tests which require special fixturing and test equipment will be sent to an independent testing laboratory.

5.0 MATERIAL PROCUREMENT

5.1 MATERIAL AND VENDOR EVALUATION (Polyimide glass only)

Material samples will be procured from 8 vendors or at least from those of the 8 who are willing to participate in the program. Along with the samples will be accompanied specification sheets and other technical data related to each suppliers material. The properties of each material will be compared and tests will be performed on the materials. From the comparative property data and from the corresponding properties tested, the 3 suppliers with obviously superior material will be selected. If more than 3 suppliers appear to have equally good material, three will be selected which have lower cost and the best production capability.

5.2 SINGLE SUPPLIER SELECTION (Polyimide glass only)

From the three (3) suppliers selected in the vendor evaluation, material in sufficient quantity will be ordered to perform the testing specified. The materials for each vendor will be tested per Table 4-1, 4-2, and 4-3 of this NOSC contract and test results will be evaluated. Based on this evaluation the best material will be used in activity #6, fabrication and process development.

5.3 PROCUREMENT OF DUPONTS POLYIMIDE FLEX MATERIAL WITH ACRYLIC ADHESIVE

The DuPont pyra-lux flexible material system will be used in this program as a continuation of a previous Navy contract on flex harnesses. Tests will be performed per a General Dynamics test procedure and corresponding material requirements will be met.

6.0 FABRICATION AND PROCESS DEVELOPMENT

This activity will consist of fabricating test panels of various complexity and of fabricating the most difficult of the SM-2 missile rigid flex harnesses. In fabricating these harnesses all of the best individual processes from activity 3 will be put together in order to optimize the total process and achieve the goal of an overall 85% yield in production.

Individual process parameters will be varied within acceptable ranges in order to increase product quality and decrease costs. After achieving the best combination of individual processes, all pertinent information will be drafted into a process specification.

The final set of hardware will be manufactured in the General Dynamics production facility, using production operators, materials which meet the documented material specification, and processes specified by the documented process specification developed in this report. This will allow a realistic conclusion to be drawn in activity 7 and 8 as to the projected production yield.

7.0 TEST AND EVALUATION

The product tests performed on fabricated hardware will begin as soon as the first pieces of prototype hardware are built and will proceed on all subsequent hardware as well. The requirements and test procedures will be spelled-out in the product specification which will be written as a result of this program. This product specification will be written from many requirements and test procedures contained in MIL-P-55640 and will contain others as needed.

As the testing proceeds from the initial test hardware to the final SM-2 missile harness submitted to NOSC, data will be collected and evaluated to determine all of the most pertinent requirements for rigid-flex harnesses. This collection of requirements and tests will help in writing the final report specification.

The deliverable hardware will all meet the requirements specified in the product specification and these requirements will meet or exceed the present SM-2 missile harness requirements.

8.0 YIELD AND COST ANALYSIS

A cost comparison of the present process versus the newly developed process will be performed. Since overhead costs are constant for both processes they will not be considered. Instead, material cost differentials, yield figures, and reductions in processing costs will be considered.

The yield figures for the current process will be obtained as close as possible for the past 12 months of production. The average for these figures will be compared to a projected yield, using the figures from the production built harnesses to be submitted in this contract.

9.0 PREPARATION AND SUBMISSION OF REPORTS

9.1 TEST PLAN

Thirty days after the issuance of Contract N00123-77-C-1192 a test plan describing specific activities and the time frame to accomplish these activities will be submitted to the Naval Ocean Systems Center (NOSC).

9.2 MONTHLY REPORTS

Every 30 days from contract issuance a monthly report will be submitted to the Naval Ocean Systems Center (NOSC). The report will contain the work performed during that 30 day period whether successful or not. It will be stated whether the project is on schedule and will be reported on Form No. NSA-DI-5009A.

9.3 QUARTERLY REPORTS

Every 90 days from contract issuance a quarterly report will be submitted to the Naval Ocean Systems Center. The report will contain the work performed during that 90 day period whether successful or not. It will be stated whether the project is on schedule and will be reported on Form NSA-DI-5009A.

9.4 FINAL REPORTS

At the end of the program a final report submitted on Form No. UDI-E-21353A will be provided showing the accomplishments of all activities specified in the subject contract. Items such as process specifications, material specifications, product specifications, photographs, sketches, and drawings will be included.

10.0 PROGRAM DEBRIEFING

Thirty days prior to the end of the contract, (31 January 1979), the Navy representative will be notified, to provide sufficient time to invite all Governmental and private industry representatives to the debriefing. The debriefing will be held at the General Dynamics Pomona Division facility, or at any other place so designated by the Navy Administrative Personnel.

Providing the debriefing is held at General Dynamics, Pomona Division, a guided tour of applicable company facilities will be conducted. for those who have proper security clearances and desire to see the equipment which was used for process development.

The content of the debriefing will consist of slides, view-graphs, sample hardware, handouts and of course, a verbal narration of the entire contract content. Depending upon the Navy representatives viewpoint, the use of product trade names and company names will be avoided or minimized in this debriefing to eliminate controversy among the wide spectrum of material, chemical and equipment suppliers used in the subject process development.

The actual date and time for the debriefing will be discussed later and selected for convenience of General Dynamics and Naval personnel.

11.0 DELIVERABLES

The following hardware, specifications, presentation material, drawings, sketches and photographs necessary for a contractor to manufacture rigid-flex harnesses of the SM-2 missile complexity will be presented to the applicable Navy Personnel on or before 31 January 1979. The hardware will be legibly identified with a waterproof epoxy type ink per MIL-STD-129 and packaged using a polyethelene bubble type cushioning material.

11.1 RIGID FLEX HARNESSES

11.1.1 Six or more rigid flexible harness of a lesser complexity than the SM-2 missile design.

11.1.2 One (1) SM-2 missile rigid-flex harness of the greatest complexity. Contains 10 mil circuit line widths, 0.060-inch diameter termination pads, eight circuit layers and three distinct detail harnesses.

11.2 MATERIAL SPECIFICATIONS

11.2.1 A specification defining the physical, electrical and chemical requirements, and test procedures for the polyimide glass stiffener material will be provided. The specification will use accepted test procedures and requirements as presently exist in MIL-P-55617, MIL-P-55640, ASTM specifications and IPC specifications where possible. In addition, the data complied from the vendor surveys will be used to derive presently undefined material requirements and test procedures. The total intent of the specification is to be able to provide material which will produce a rigid flex harness that can withstand all subsequent processing and still meet flight and storage requirements.

11.2.2 A specification defining the physical, electrical, and chemical requirements and test procedures for the adhesive coated polyimide film, the cast adhesive film, and the copper clad polyimide film will be provided. The material requirement and test procedures will be taken from suppliers data, ASTM procedures, IPC procedures and Engineering derivations. The specification will be directed towards an acrylic adhesive system which is supplied from DuPont De Nemours. Most of the requirements and test procedures are defined currently in General Dynamics, Pomona Division Engineering documentation.

11.3 PROCESS SPECIFICATION

There will be one process specification which incorporates many sub-process specifications to build a rigid flex harness. The sub-process specifications will include the following processes: drilling, plating, drill smear removal, lamination, etching, and photo engraving. The process specifications will be written to provide more than one product or more than one method for performing a process. For example, 3 different electroless copper baths will be shown to copper plate hybrid-flex harness.

The specifications will show all parameters necessary for the operation of a process, such as times, temperatures, pressures, special tools, non fly-away items such as release films and chemical solutions, and equipment.

The intent of the process specification is to provide sufficient information to Navy Contractors so that they would be able to manufacture rigid flex harnesses under a variety of different processing conditions.

11.4 PRODUCT SPECIFICATION

This specification will define all of the tests and requirements which the final product (rigid-flex harness) must meet. This includes thermal cycling, electrical response, dimensional stability, and physical structure testing. The requirements and test procedures will be taken from MIL-P-55640 and MIL-P-50884 specifications where possible. Other requirements and test procedures will be added or modified where necessary.

Any special test fixtures or equipment necessary to perform the testing will be shown pictorially and described in detail.

11.5 Presentation material such as slides, view graphs pictures, handouts, drawings or sketches will be provided. The number of copies of each will be discussed at a later date.

TIME SCHEDULE

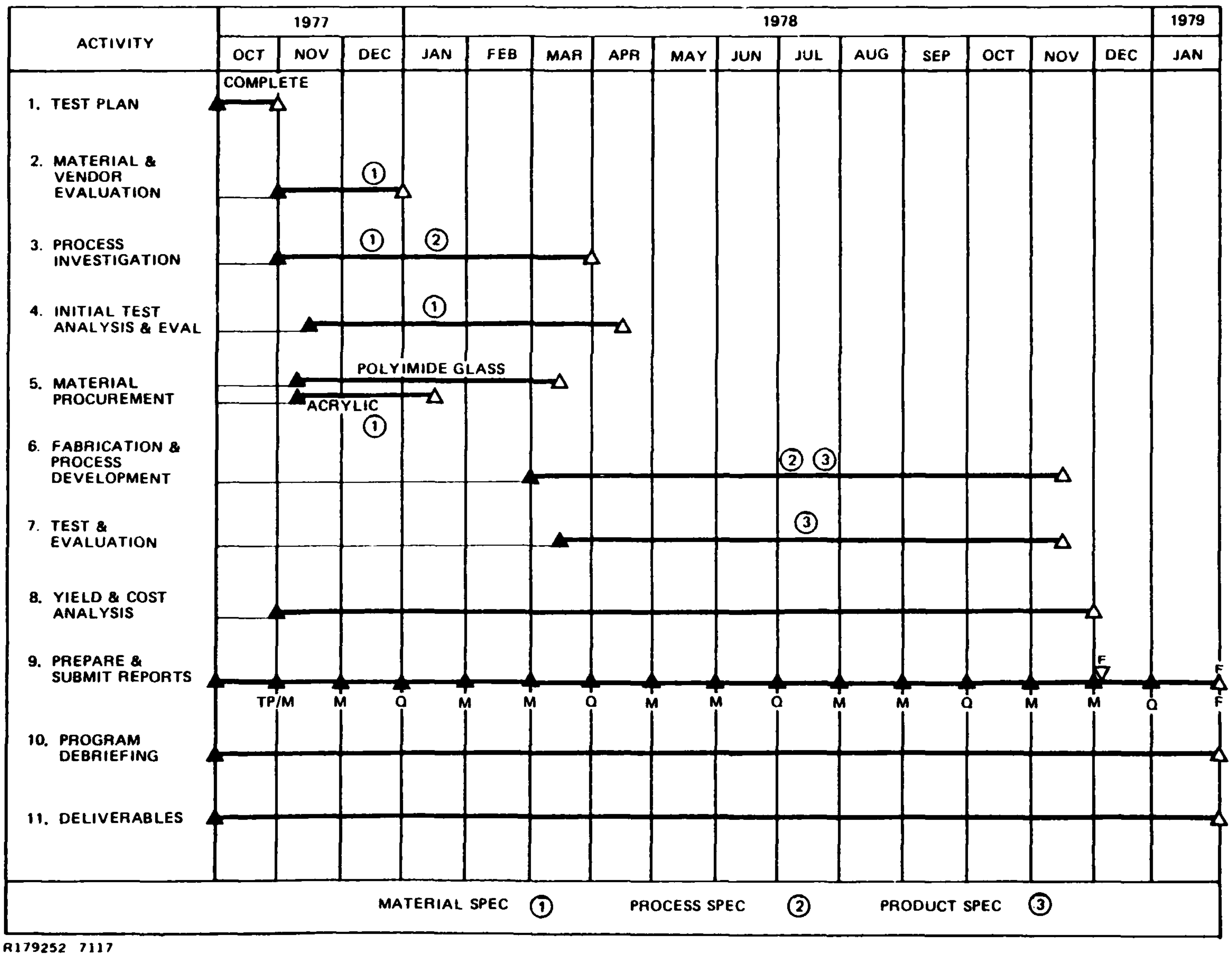


EXHIBIT 4
SAMPLE QUESTIONAIRE

Exhibit 4 Standardized Questionnaire and Check List

Supplier Plant Survey Check List

For

Navy Contract N00123-77-C-1192

Company Name ____________________
Address ____________________
____
Telephone ____________________
Representative ____________________

General Requirements:

Production

1. Number of square feet of clad produced/yr. ________________
2. Production capacity in square feet/mo. ________________
3. Produces pre-preg for own use ________________

Material

1. Copper type, grade & oxide ________________
2. Resin type, grade, etc ________________
3. Cloth supplier ________________

Plant Facilities

Prepreg Production

1. Size of resin coater
   width capacity ________________
   length capacity ________________
   resin capacity in gals. ________________
2. Drying oven or tower
   Size ________________
   Type ________________
   Speed ________________

Plant Facilities (Cont'd)

Laminating Capability

1. Press Platen sizes ____
2. Number of openings/press ____
3. Type of presses ____
4. Number of presses ____
5. Press cycle times ____
6. Calibration and control of presses ____

   Periodic ____
   In-house ____
   Method ____

Post Curing

1. Oven sizes ____
2. Oven types ____
3. Oven capacity ____
4. Number of post cure ovens ____
5. Process cycle times & temperatures ____
6. Need for additional post cure at GD/P ____

Overall Condition of Facilities

1. Approximate age ____
2. Relative condition (appearance from 1 to 3 with 1 being excellent, 2 acceptable and 3 unacceptable) ____

Quality Control

1. Laboratory test facilities

   Own Lab % ____
   Outside Lab % ____
   Types of tests sent out ____
   Laboratories used ____

2. Certifies material to meet MIL-P-55617 Reqt's. ____

   Exceptions ____

Quality Control (Cont'd)

3. Special handling techniques ______________________

4. Environmental conditions (control of)

   Temperature ______________________
   Air Flow ______________________
   Relative Humidity ______________________
   Dust and particle ______________________
   Chemical reagents ______________________
   Grease, oils, finger prints & soils ______________________

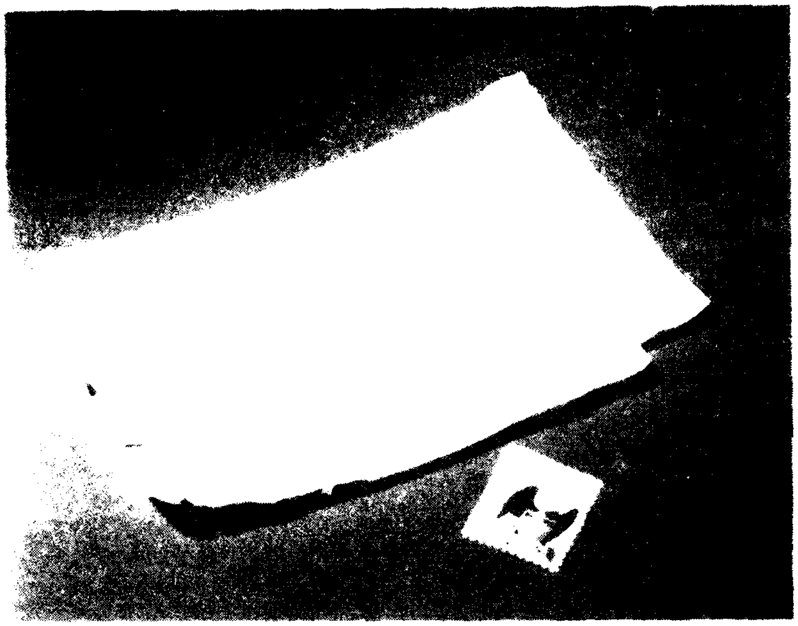
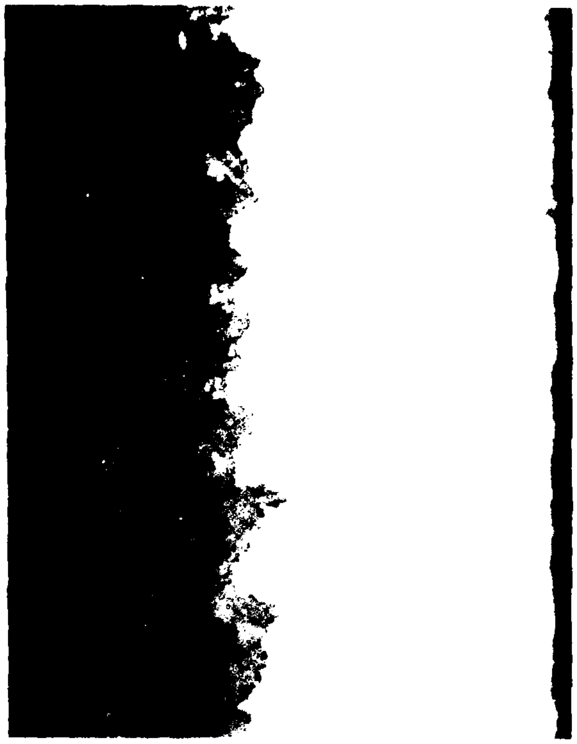


EXHIBIT 5. 2 Plys of 116 Sylane Treated Glass Cloth Typically Used in the Construction of All Polyimide Glass Laminates

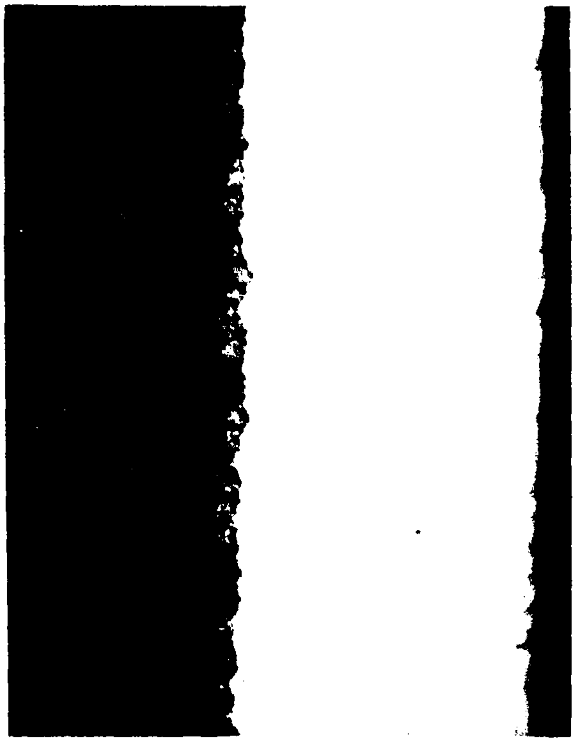
EXHIBIT 6
COPPER FOIL SURFACE CONDITION

SUPPLIER "A" at 1000 X

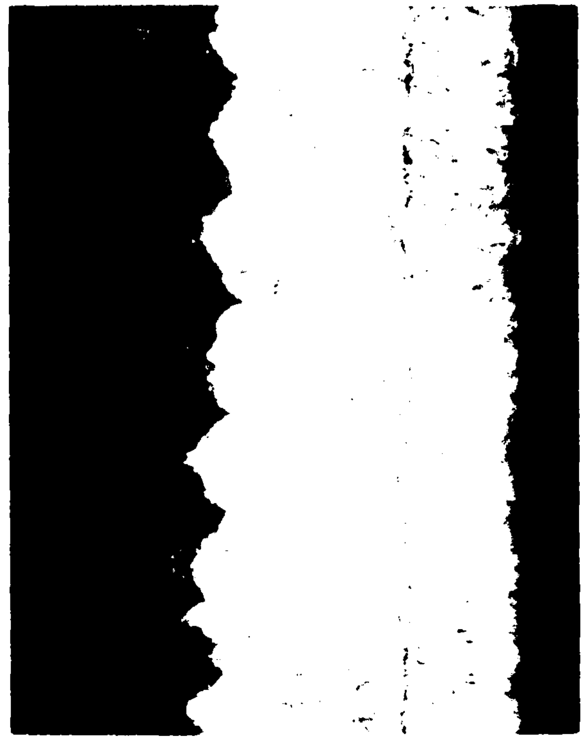


SUPPLIER "B" at 1000 X

EXHIBIT 6
Photomicrographs of the Copper Foil
Surface Laminated to the Polyimide Glass

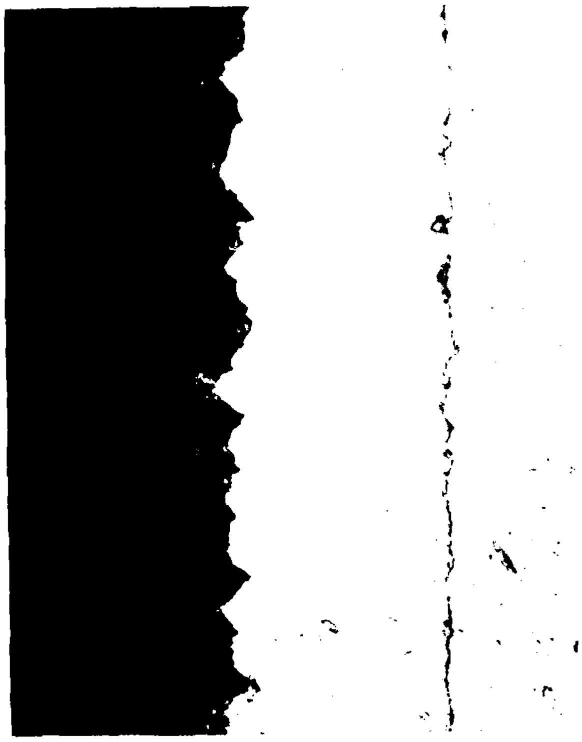


SUPPLIER "C" at 1000 X

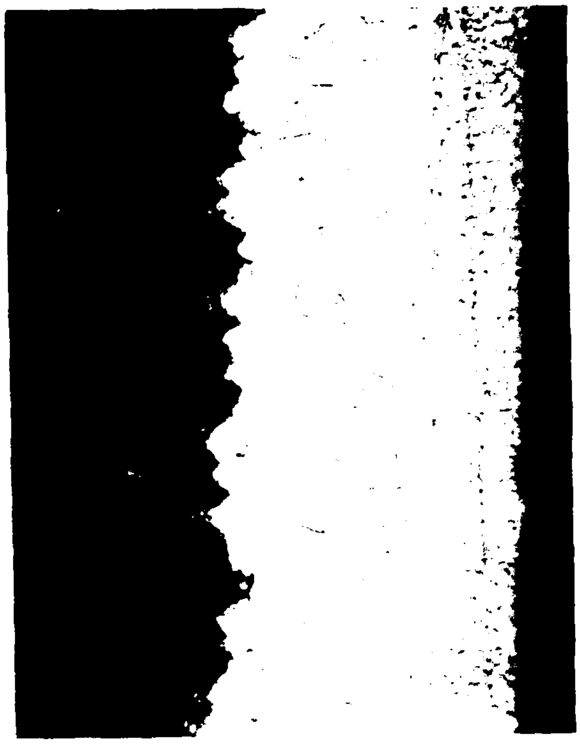


SUPPLIER "D" at 1000 X

EXHIBIT 6
Photomicrographs of the Copper Foil
Surface Laminated to the Polyimide Glass

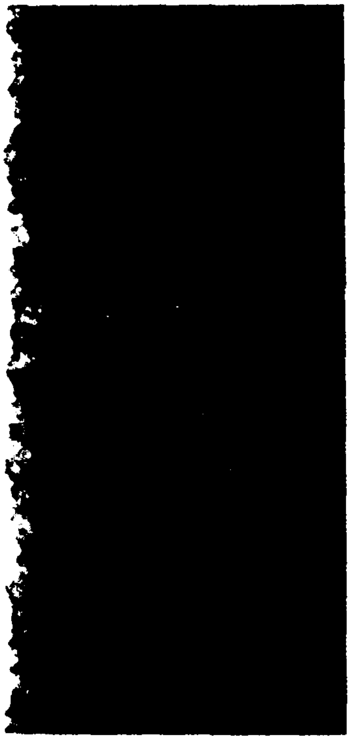


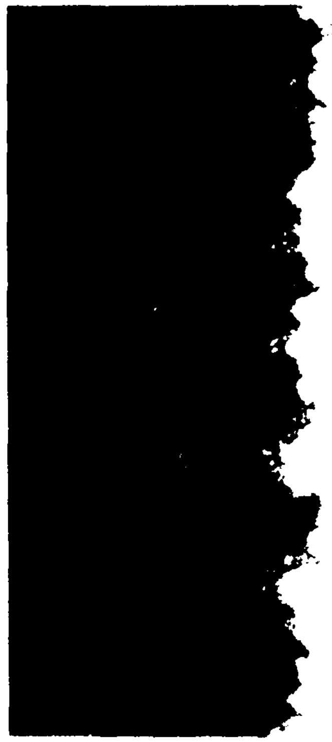
SUPPLIER "E" at 1000 X



SUPPLIER "F" at 1000 X

EXHIBIT 6
Photomicrographs of the Copper Foil
Surface Laminated to the Polyimide Glass





SUPPLIER "G" at 1000 X

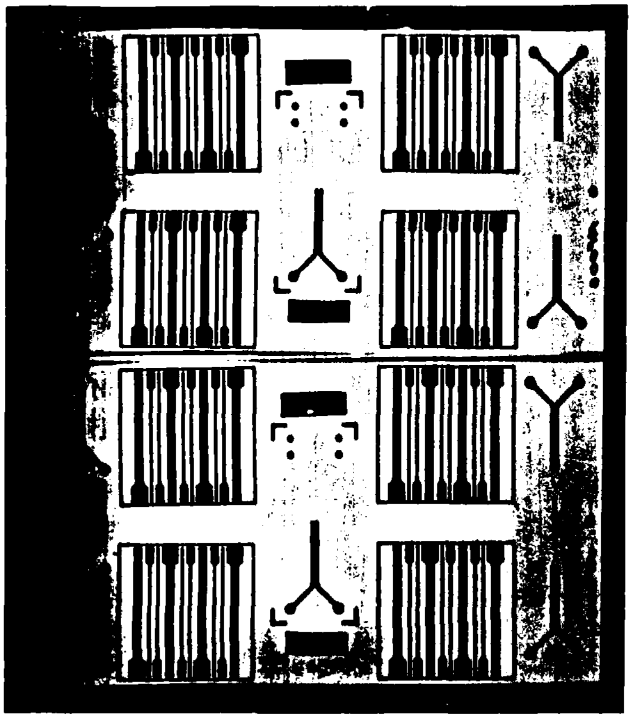
SUPPLIER "B" EPOXY GLASS at 1000 X

Photomicrographs of the Copper Foil
Surface Laminated to the Polyimide Glass

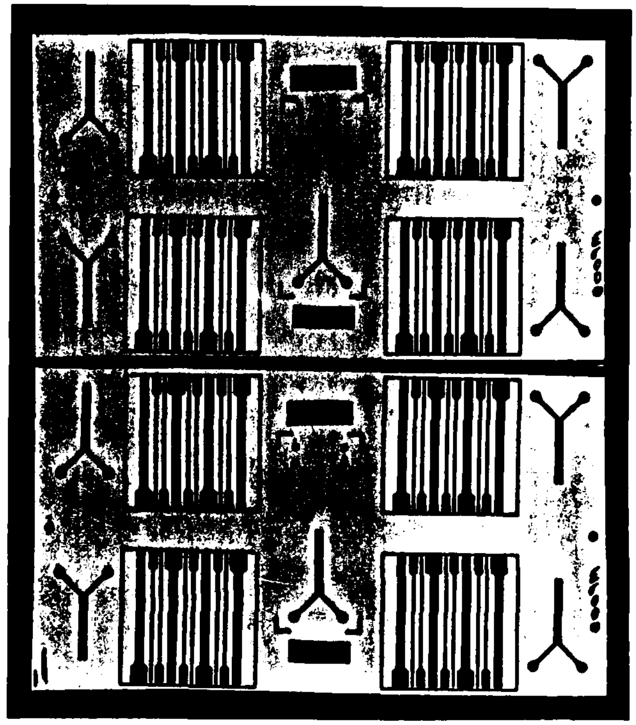
EXHIBIT 7

LAMINATE COLORATION AND CLARITY

LAMINATE COLORATION



SUPPLIER "E"

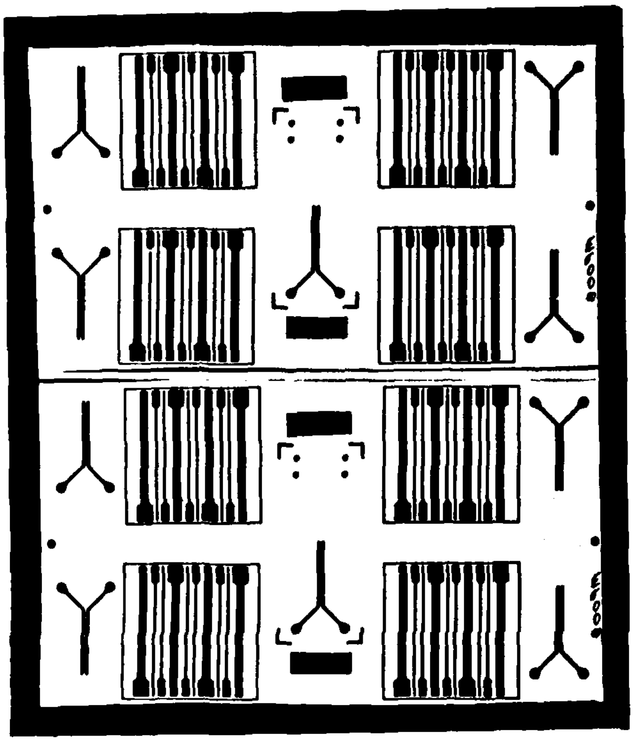


SUPPLIER "F"

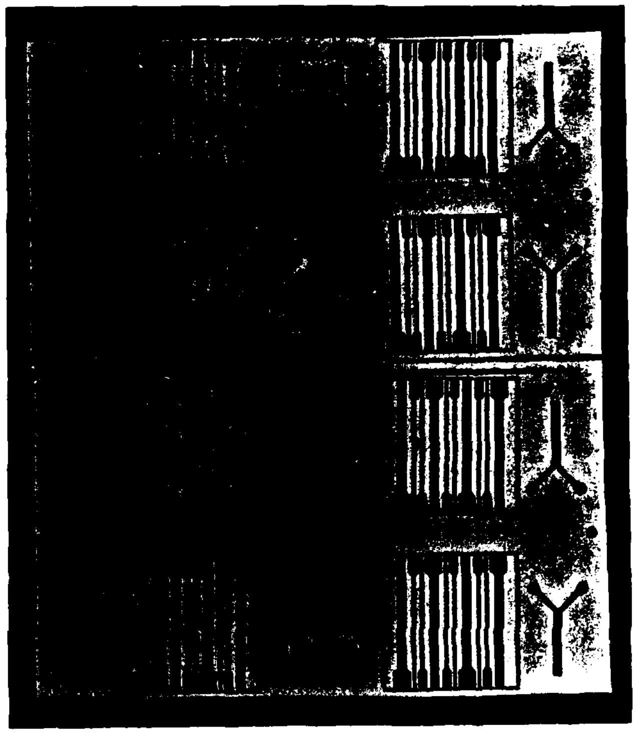
EXHIBIT 7 Photos of a 9" x 12" Polyimide Glass Laminate Panel With a Peel Test Pattern Etched in the Copper

72 blank

LAMINATE COLORATION



SUPPLIER "B"



SUPPLIER "D"

EXHIBIT 7 Photos of a 9" x 12" Polyimide Glass Laminate Panel With a Peel Test Pattern Etched in the Copper

LAMINATE COLORATION

SUPPLIER "G"

EXHIBIT 7 Photos of a 9" x 12" Polyimide Glass Laminate Panel With a Peel Test Pattern Etched in the Copper

EXHIBIT 8
TEST DATA
FOR
VENDOR EVALUATION

NUMBER 1

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 12-9-77

TYPE OF TEST SURFACE FINISH

EQUIPMENT REQUIRED BENDIX PROFILOMETER

SPECIFICATION MIL-P-55617B

MIN/MAX VALUE MAX 20 MICROINCHES

UNITS OF RECORDED VALUES MICRO INCHES

TEST PERFORMED BY E. MC GUIRE

MATERIAL DESCRIPTION AND SUPPLIER .010" CORE POLYIMIDE GLASS 1 OZ COPPER 1 SIDE

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1	A	12-15 12-15 10-15			
2	A	12-16 12-15 11-14			
3	B	14-17 14-16 13-15			
4	B	13-16 13-15 13-16			
5	D	11-13 11-14 11-14			
6	D	13-16 11-13 12-14			
7	E	10-15 12-15 12-15			
8	E	12-15 13-15 14-15			
9	F	14-16 14-17 15-18			
10	F	13-15 14-18 13-16			
11	G	10-13 11-16 11-16			
12	G	13-18 10-13 12-18			
13					
14					
15					
16					
17					
18					
19					
20					

OBSERVATIONS NOTE! VALUES WERE IN FILL OR TRANSVERSE DIRECTION

NUMBER 2

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 12-8-77

TYPE OF TEST SURFACE FINISH

EQUIPMENT REQUIRED BENDIX PROFILOMETER

SPECIFICATION MIL-P-55617B

UNITS OF RECORDED VALUES MICRO INCHES

MIN/MAX VALUE MAX 20 MICRO INCHES

TEST PERFORMED BY E McGUIRE

MATERIAL DESCRIPTION AND SUPPLIER .010" CORE POLYIMIDE GLASS LAMINATE 1 oz COPPER 1 SIDE

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES			CALC. AVG.		SUPPLIER RANKING
1	A	5-7	8-12	8-11			
2	A	6-10	7-10	4-6			
3	B	8-11	8-12	11-14			
4	B	10-14	8-14	12-15			
5	D	5-8	5-7	6-8			
6	D	5-8	4-7	5-9			
7	E	8-10	6-10	6-10			
8	E	5-10	5-10	6-12			
9	F	7-10	8-11	8-10			
10	F	7-10	7-10	7-10			
11	G	4-9	4-11	4-6			
12	G	4-6	4-7	4-7			
13							
14							
15							
16							
17							
13							
19							
20							

OBSERVATIONS

NOTE: VALUES WERE IN WARP OR MACHINE DIRECTION

NUMBER 3

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 12-8-77

TYPE OF TEST THICKNESS

EQUIPMENT REQUIRED STARRETT 1" THROAT VERNIER MICROMETER

SPECIFICATION MIL-P-55617B

UNITS OF RECORDED VALUES INCHES

MIN/MAX VALUE .0094 MIN .00114 NOMINAL .00134 MAX

TEST PERFORMED BY J. A. REAVILL

MATERIAL DESCRIPTION AND SUPPLIER .010" CORE POLYIMIDE GLASS 1 OZ COPPER CLAD ONE SIDE

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1	A	.0108, .0105, .0112, .0113, .0106	[illegible]		2
2	A	.0112, .0110, .0115, .0111, .0112	[illegible]		
3	B	.0110, .0112, .0110, .0113, .0115	[illegible]		1
4	B	.0115, .0110, .0110, .0115, .0110	[illegible]		
5	D	.0130 .0125 .0130 .0130 .0125	.0128		4
6	D	.0120 .0125 .0115 .0130 .0120	.0122		
7	E	.0120 .0125 .0120 .0120 .0120	.0121		3
8	E	.0120 .0124 .0120 .0125 .0120	.0122		
9	F	.0119 .0115 .0120 .0114 .0120	.0118		2
10	F	.0114 .0123 .0115 .0115 .0118	.0117		
11	G	.0130, .0135, .0130, .0130 .0135	.0132		5
12	G	.0130 .0130 .0135 .0130 .0130	.0131		
13					
14					
15					
16					
17					
18					
19					
20					

OBSERVATIONS

NUMBER 4

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 12-9-77

TYPE OF TEST COPPER PEEL - AFTER ETCHING / AFTER ELEVATED TEMP EQUIPMENT REQUIRED INSTRON TENSIL MACHINE

SPECIFICATION MIL-P-55617B

MIN/MAX VALUE 5 LB/IN MIN

UNITS OF RECORDED VALUES LB/IN OVEN - 204 °F

TEST PERFORMED BY T. [illegible] / J. [illegible]

MATERIAL DESCRIPTION .010" CORE POLYIMIDE GLASS 1 OZ COPPER CLAD ONE SIDE

AND SUPPLIER

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.	CALC FOR 1" WIDE	SUPPLIER RANKING
1	A	1.05 .93 .90 .85	.94	7.5	4
2	A	1.03 .99 .95 .98	.99	7.9	
3	B	1.10 1.05 1.04 1.11	1.08	8.6	2
4	B	1.11 1.08 1.11 1.10	1.10	8.8	
5	D	1.0 1.0 1.0 .95	.99	7.9	3
6	D	1.08 1.03 1.0 1.14	1.06	8.5	
7	E	.78 .82 .83 .80	.81	6.4	6
8	E	.78 .75 .80 .77	.79	6.0	
9	F	1.12 1.14 1.10 1.10	1.12	9.0	1
10	F	1.10 1.10 1.11 1.08	1.10	8.8	
11	G	.92 .92 .92 .92	.92	7.4	5
12	G	.92 .88 .92 .94	.92	7.4	
13	EPOXY	1.04 1.02 1.0 1.1	1.02	8.16	
14	EPOXY	1.1 1.12 1.09 1.1	1.10	8.8	
15					
16					
17					
18					
19					
20					

OBSERVATIONS NO SAMPLES FAILED

NUMBER 5

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 12-9-77

TYPE OF TEST Copper Peel - After Etching / After Solder Dip

EQUIPMENT REQUIRED Instron Tensil Machine

SPECIFICATION MIL-P-55617B

MIN/MAX VALUE 5 lb min

UNITS OF RECORDED VALUES lbs

Solder Pot 500°F +9°F -0

Oven

TEST PERFORMED BY T. [illegible] / J. [illegible]

MATERIAL DESCRIPTION AND SUPPLIER .010" Core Polyimide Glass 1 oz. Copperclad One Side

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.	[illegible]	SUPPLIER RANKING
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	
3	[illegible]	[illegible]	[illegible]	[illegible]	1
4	[illegible]	[illegible]		[illegible]	
5	[illegible]	[illegible]	[illegible]	[illegible]	2
6	[illegible]	[illegible]	[illegible]	[illegible]	
7	[illegible]	[illegible]		[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	
9	[illegible]	[illegible]	[illegible]	[illegible]	3
10	[illegible]	[illegible]	[illegible]	[illegible]	
11	[illegible]	[illegible]	[illegible]	[illegible]	5
12	[illegible]	[illegible] 76	[illegible]	[illegible]	
13	[illegible]	[illegible]	[illegible]	[illegible]	
14	[illegible]	[illegible]	[illegible]	[illegible]	
15					
16					
17					
18					
19					
20					

OBSERVATIONS No samples failed

NUMBER 6

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 12-9-77

TYPE OF TEST Copper Peel – ~~As Received~~ After Etching

EQUIPMENT REQUIRED Instron Tensil Testing Machine

SPECIFICATION MIL-P-55617B

MIN/MAX VALUE 5 lb MIN

UNITS OF RECORDED VALUES lb

TEST PERFORMED BY T. Apodaca

MATERIAL DESCRIPTION AND SUPPLIER .010" core polyimide glass 1 oz copper clad one side

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.	CALC FOR 1" WIDE	SUPPLIER RANKING
1	A	.74, .85, .74, .72	.76	6.0	3
2	A	.92, .94, .94, .95	.93	7.4	
3	B	1.04, 1.02, 1.0, 1.02	1.02	8.2	1
4	B	1.01, .98, 1.01, 1.0	1.01	8.1	
5	D	.86, .85, .86, .85	.86	6.9	4
6	D	.85, .81, .83, .78	.82	7.0	
7	E	.65 .65 .66 .66	.66	5.3	
8	E	.72 .72 .72 .71	.72	5.8	6
9	C	.98 1.0 1.04 .95	1.0	8.0	2
10	F	.99 1.0 .98 .96	.98	7.8	
11	G	.87 .87 .90 .84	.87	7.0	5
12	G	.86 .84 .82 .80	.84	6.7	
13	Epoxy Glass	.98 .95 .99 .99	.99	7.9	
14	" "	1.03 1.0 1.02 1.0	1.01	8.1	
15					
16					
17					
18					
19					
20					

OBSERVATIONS

NO SAMPLES FAILED

NUMBER 7

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 12-15-77

TYPE OF TEST PEEL TEST - KAPTON PLASMA TREATED TO POLYIMIDE GLASS PLASMA TREATED BONDED WITH ACRYLIC ADHESIVE

EQUIPMENT REQUIRED INSTRON TENSIL TESTING MACHINE, SOLDER POT

SPECIFICATION —

MIN/MAX VALUE —

UNITS OF RECORDED VALUES lbs

TEST PERFORMED BY J A REAVLL

NOTE; SAMPLES WERE IMMERSED IN MOLTEN SOLDER FOR 20 SECONDS AT 550°F

MATERIAL DESCRIPTION .010 POLYIMIDE GLASS/1oz COPPER CLAD ONE SIDE .002 ACRYLIC ADHESIVE .001 KAPTON COVERLAY

AND SUPPLIER SEE EXHIBIT.

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.	FAILURE TYPES	SUPPLIER RANKING
1	A	9.0, 8.0, 7.5	8.1	NO BLISTER COHESIVE	6
2	B	9.0, 12.0, 8.0	9.3	BLISTERED COH. & ADH.	5
3	D	10.0, 8.0, 13.0	10.3	BLISTER COHESIVE	4
4	E	12.6, 12.5, 15.0	13.3	NO BLISTER COHESIVE	1
5	F	12.6, 12.0, 8.0	10.9	NO BLISTER COHESIVE	2
6	G	12.0, 7.5, 13.0	10.8	BLISTERS COH & ADH.	3
7	EPOXY	[illegible]	15.1		
8	EPOXY	[illegible]	16.0		
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

OBSERVATIONS SAMPLES PEELED AT HIGH VALUES
SAMPLES B, D, & G BLISTERED
SAMPLES D & G GLASS CLOTH SEPARATED

NUMBER 8

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 12 - 15 - 77

TYPE OF TEST PEEL TEST - KAPTON PLASMA TREATED TO POLYIMIDE GLASS PLASMA TREATED WITH ACRYLIC ADHESIVE

EQUIPMENT REQUIRED INSTRON TENSIL TESTING MACHINE

SPECIFICATION —

MIN/MAX VALUE —

UNITS OF RECORDED VALUES lbs

TEST PERFORMED BY J. A. REAVILL

MATERIAL DESCRIPTION .010" POLYIMIDE GLASS 1OZ CU CLAD ONE SIDE
.002" ACRYLIC ADHESIVE
.001" KAPTON COVERLAY

AND SUPPLIER SEE EXHIBIT FOR CONSTRUCTION

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1	A	15.0, 12.5, 12.5	12.3		4
2	B	18.5 16.5 16.0	17.0		1
3	D	11.0 15.0 15.0	13.9		3
4	E	20.0 15.0 15.0	16.6		2
5	F	12.6 12.0 10.0	11.5		5
6	G	7.5 8.0 6.0	7.1		6
7	EPOXY	17.0 12.0 15.0	17.5		
8	EPOXY	13.5 15.0 13.5	15.4		
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

OBSERVATIONS MOST FAILURE OF MATERIALS WAS COHESIVE – RESIN IN POLYIMIDE GLASS PULLED OUT OF CLOTH

NUMBER 9

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 12-22-77

TYPE OF TEST DIMENSIONAL STABILITY AFTER ETCHING AND ELEVATED TEMP

EQUIPMENT REQUIRED BORROW DALE-OPTIPLOT WITH A CIRCON MICRO TECH VIDEO SYSTEM (50X TV SCREEN) AND A HEIDENHAIN DIGITAL READ-OUT

EXCELLON DIGITAL DRILLING MACHINE OVEN

SPECIFICATION MIL-P-55617B

UNITS OF RECORDED VALUES INCHES PER INCH

MIN/MAX VALUE .0003 INCHES/INCH

TEST PERFORMED BY J. A. REAVILL

MATERIAL DESCRIPTION .010" POLYIMIDE GLASS LAM 1 OZ CU ONE SIDE ONLY

AND SUPPLIER

SAMPLE #	SUPPLIER CODE LETTER	DIRECTION RECORDED VALUES MACHINE	TRANSVERSE	CALC. AVG.		SUPPLIER RANKING
1	A EDGE	+.00008	+.00003			1
2	A MIDDLE	+.00005	+.00008			
3	B EDGE	-.00046	-.00047			6
4	B MIDDLE	-.00044	-.00045			
5	D EDGE	-.00039	-.00046			5
6	D MIDDLE	-.00048	-.00043			
7	E EDGE	-.00044	-.00036			4
8	E MIDDLE	-.00044	-.00032			
9	F EDGE	-.00037	-.00032			3
10	F MIDDLE	-.00050	-.00056			
11	G EDGE	-.00034	-.00042			2
12	G MIDDLE	-.00016	-.00021			
13	EPOXY EDGE	+.00015	-.00025			
14	EPOXY MIDDLE	-.00003	-.00028			
15						
16						
17						
18						
19						
20						

OBSERVATIONS

NUMBER 10

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 12 - 22 - 77

TYPE OF TEST DIMENSIONAL STABILITY AFTER ETCHING

SPECIFICATION MIL-P-55617B

MIN/MAX VALUE .0003"/INCH

EQUIPMENT REQUIRED BORROWDALE - OPTIPLOT WITH CIRCON MICRO TECH VIDEO SYSTEM (50X TV SCREEN) AND HEIDENHAIN DIGITAL READ-OUT

EXCELLON DIGITAL DRILLING MACHINE

UNITS OF RECORDED VALUES INCHES PER INCH

TEST PERFORMED BY G. CLARK & J.A. REALICL

MATERIAL DESCRIPTION AND SUPPLIER 0/0 POLYIMIDE GLASS LAM 1 OZ CU 1 SIDE

SAMPLE #	SUPPLIER CODE LETTER	DIRECTION RECORDED VALUES MACHINE	TRANSVERSE	CALC. AVG.	PASS/FAIL	SUPPLIER RANKING
1	A EDGE	-.00004	-.00007		PASS	2
2	A MIDDLE	-.0001	-.00005		PASS	
3	B EDGE	-.00036	-.00029		FAIL	6
4	B MIDDLE	+.00034	-.00021		FAIL	
5	D EDGE	-.00014	-.00010		PASS	5
6	D MIDDLE	-.00049	-.00033		FAIL	
7	E EDGE	-.00032	-.00010		FAIL	4
8	E MIDDLE	+.00025	-.00011		PASS	
9	F EDGE	-.00028	-.00020		PASS	3
10	F MIDDLE	-.00017	-.00012		PASS	
11	G EDGE	-.00003	+.00009		PASS	1
12	G MIDDLE	-.00008	+.00004		PASS	
13	EPOXY EDGE	+.00001	-.0002		PASS	
14	EPOXY MIDDLE	-.00018	-.00004		PASS	
15						
16						
17						
18						
19						
20						

OBSERVATIONS VENDORS A, G, AND F PASSED THIS TEST

NUMBER 11

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 1-5-78

TYPE OF TEST COPPER PEEL - AFTER ETCHING - AFTER PLATING SOL

EQUIPMENT REQUIRED INSTRON TENSIL TESTING MACHINE

SPECIFICATION MIL-P-55617

MIN/MAX VALUE 5 lb MIN

UNITS OF RECORDED VALUES lbs

TEST PERFORMED BY H. GARCIA / P. FRAZIER / J. REAVILL

MATERIAL DESCRIPTION AND SUPPLIER .010 CORE POLYIMIDE GLASS 1 OZ COPPER CLAD ONE SIDE

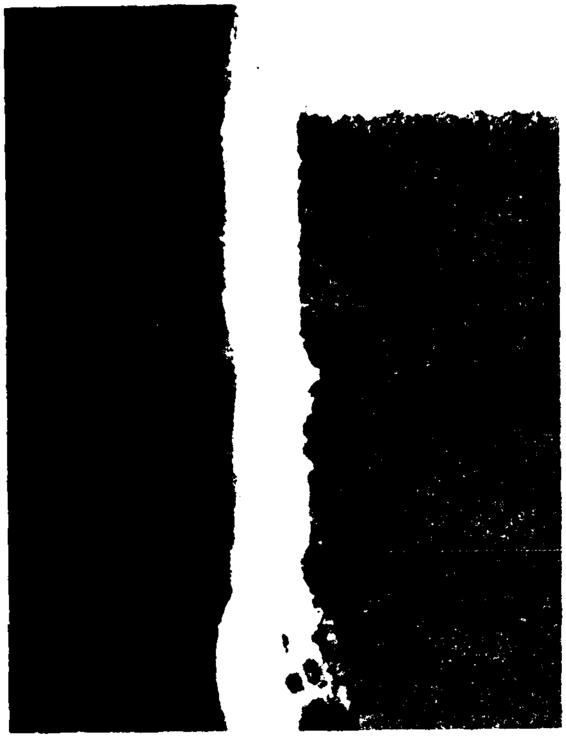
PLATING SOLUTIONS PER THE MIL-SPEC

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.	CALC FOR 1" WIDE	SUPPLIER RANKING
1	A	.25 .25 .26 .24	.25	8.[illegible]	2
2	B	.22 .23 .23 .22	.23	7.4	3
3	D	.27 .29 .29 .28	.28	9.0	1
4	E	.22 .21 .21 .21	.21	6.7	5
5	F	.05 .08 .07 .05	.07	2.2	6
6	[illegible]	.22 .20 .22 .22	.22	7.0	4
7	[illegible]	.24 .24 .25 .24	.24	7.7	
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

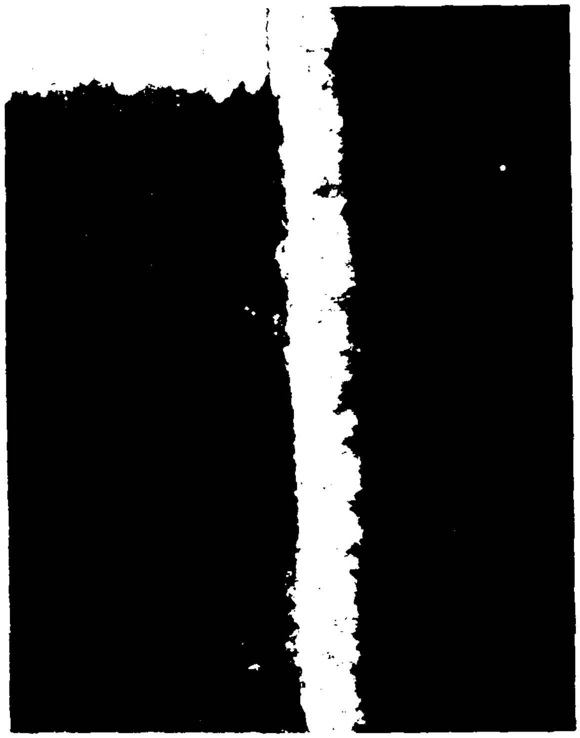
OBSERVATIONS

F - FAILED

EXHIBIT 9
DRILLED HOLES IN
POLYIMIDE GLASS LAMINATE

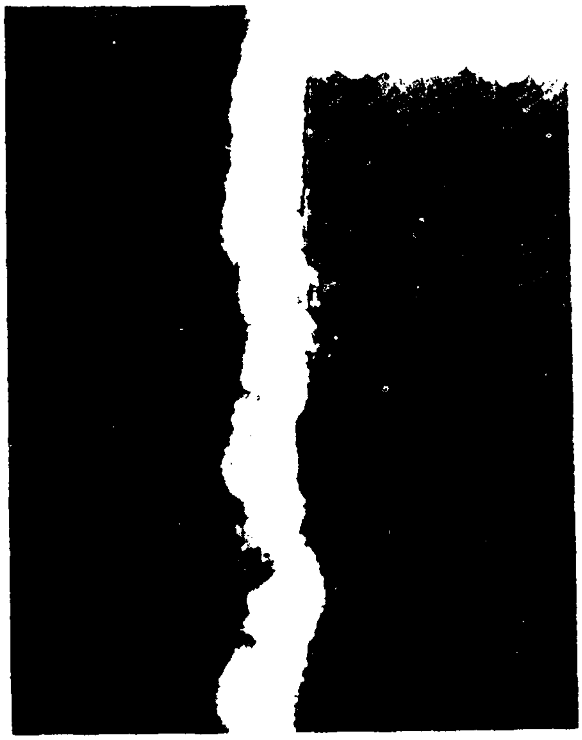


SUPPLIER "A" at 500 X

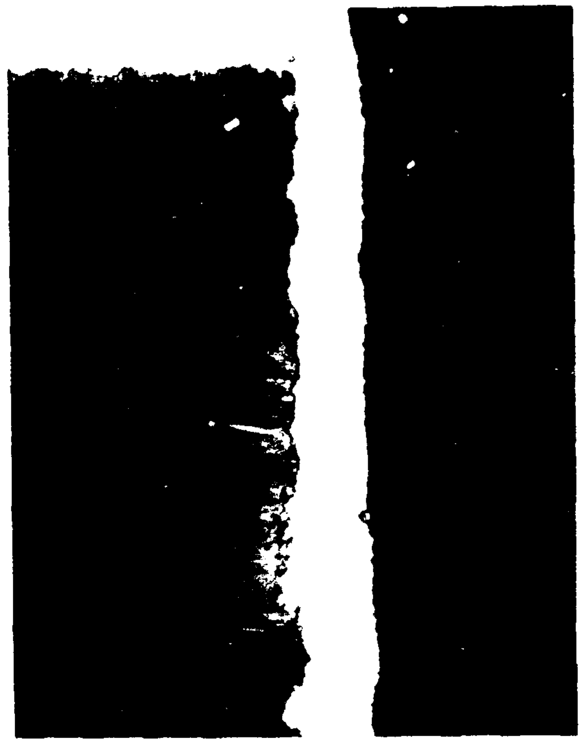


SUPPLIER "B" at 500 X

EXHIBIT 9
Photomicrographs of a Portion of a Plated-Through-Hole.
Shows Only the Area in the Polyimide
Glass (Drilled and Plated Through)

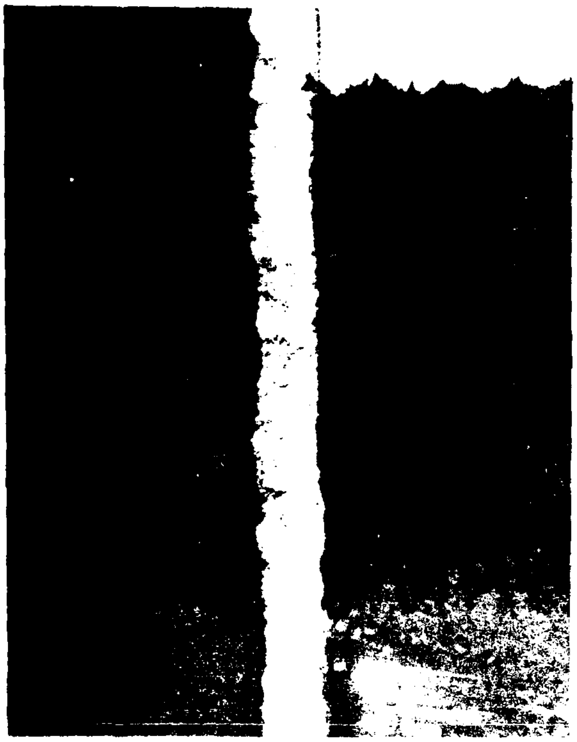


SUPPLIER "D" at 500 X

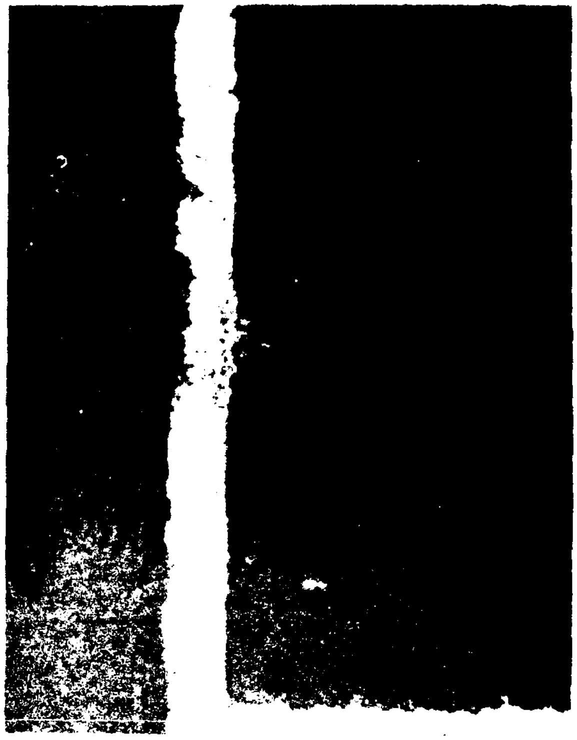


SUPPLIER "E" at 500 X

EXHIBIT 9
Photomicrographs of a Portion of a Plated-Through-Hole.
Shows Only the Area in the Polyimide Glass
Laminate (Drilled and Plated)



SUPPLIER "F" at 500 X



SUPPLIER "G" at 500 X

EXHIBIT [illegible]

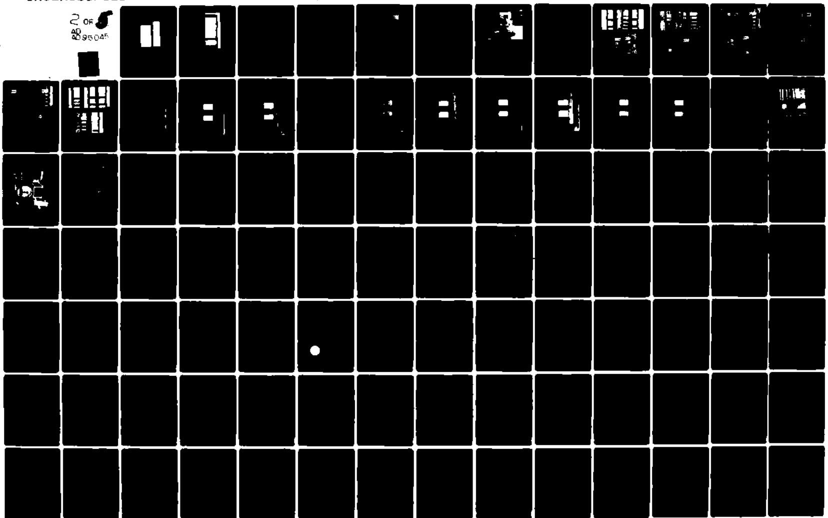
Photomicrographs [illegible] Through Hole,

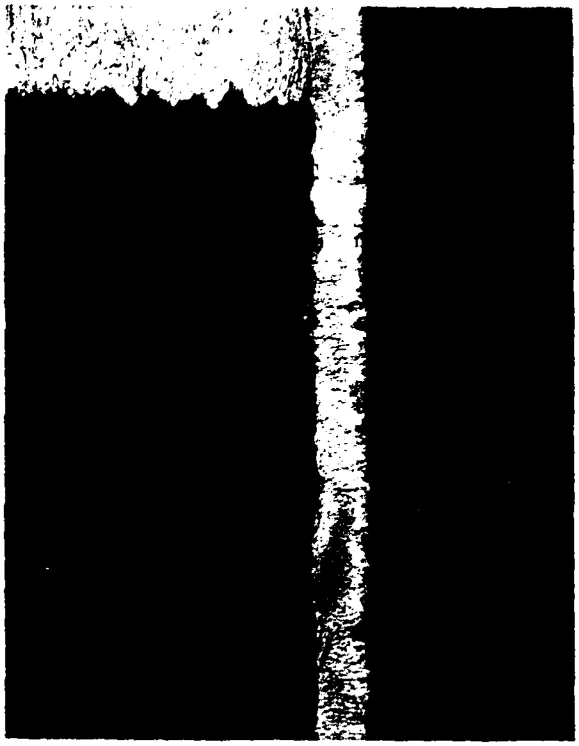
Show[illegible] [illegible]

[illegible]

AD-A095 045 GENERAL DYNAMICS CORP POMONA CA POMONA DIV F/G 9/5
RIGID-FLEX PRINTED CIRCUIT MANUFACTURING PROCESS. A PROJECT OF --ETC(U)
JUN 79 J A REAVILL N00123-77-C-1192
UNCLASSIFIED NAVSEA-MT-S-479-77 NL

2 OF 5
AD
A095045





EPOXY GLASS AT 500 X

EXHIBIT 9
Photomicrograph of a Portion of a Plated-Through-Hole.
Shows Only the Area in the Polyimide Glass
Laminate (Drilled and Plated)

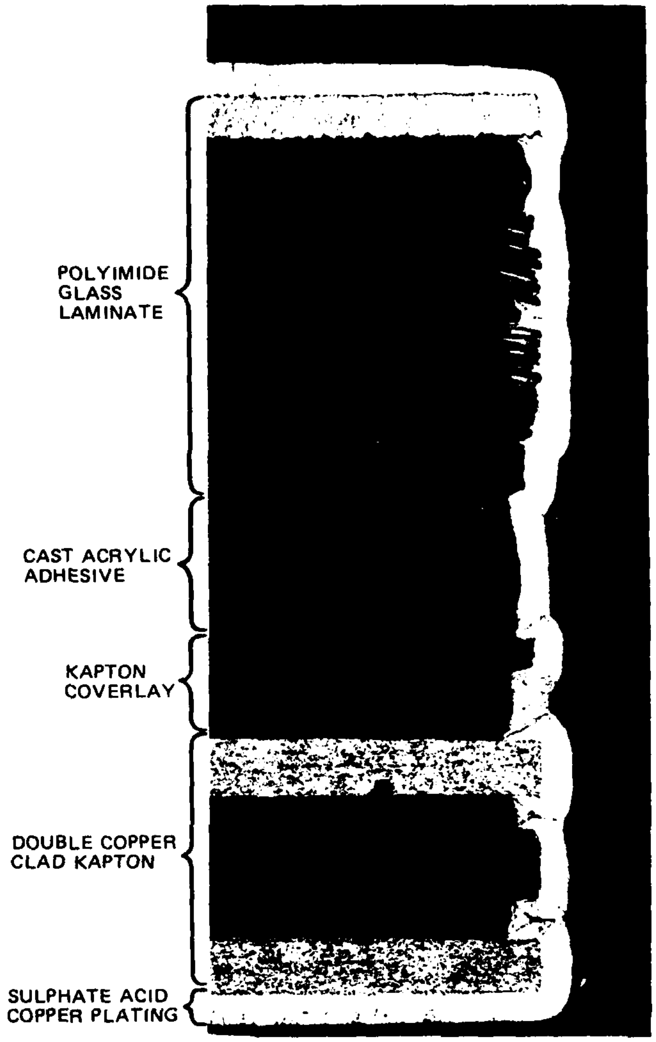


EXHIBIT 10. Photomicrograph of a Plated-Through-Hole of the Construction Shown in Exhibit 2. Shows Etch Back of Gas Plasma on the Laminate. This was Typical of all Vendors Laminate.

EXHIBIT 11
PEEL TEST STRIPS

EXHIBIT 11
1" Wide Strips Laminated of the
Construction Shown in Exhibit 10

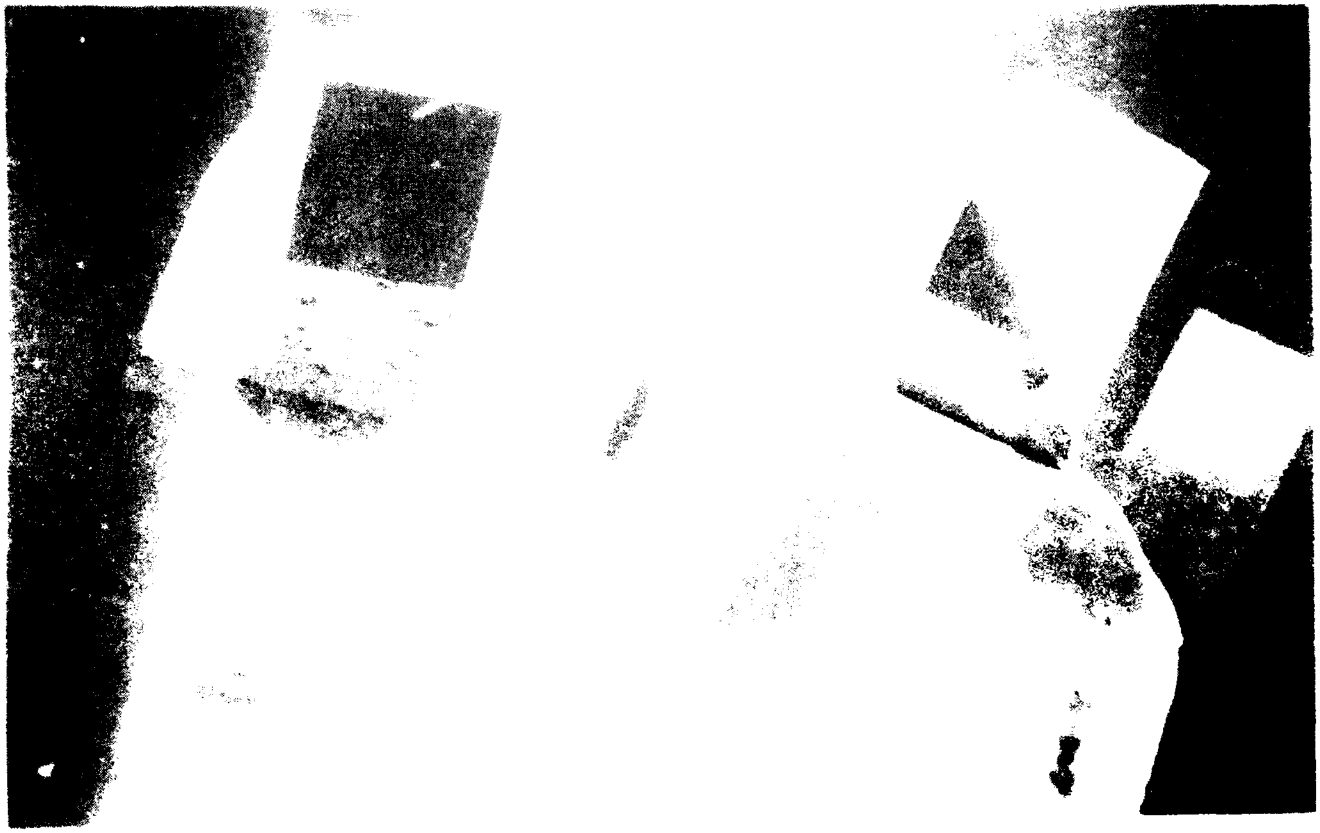
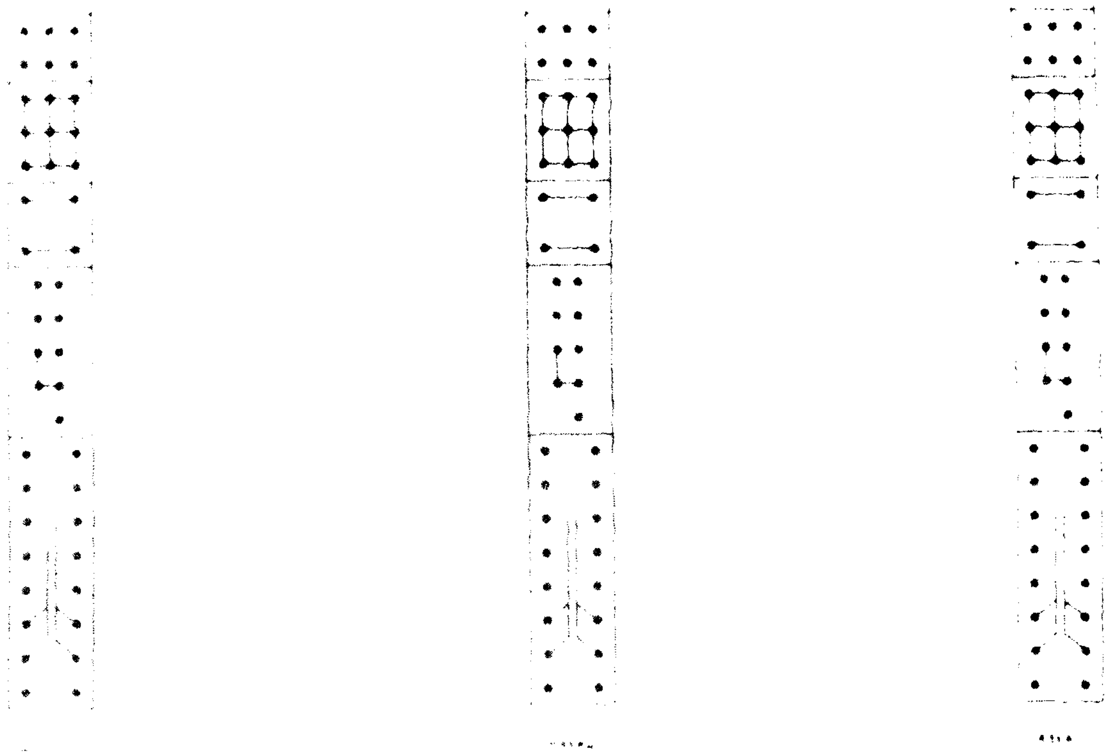


EXHIBIT 11
1" Wide Strips Laminated of the
Construction Shown in Exhibit 10

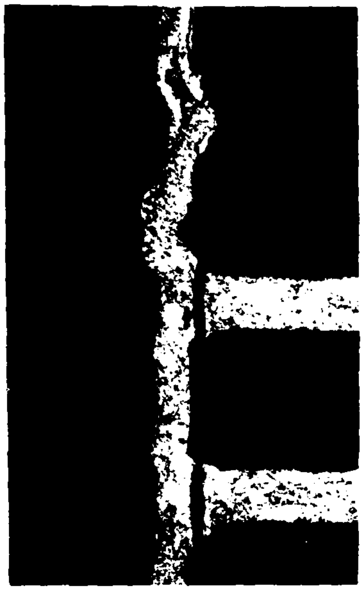


A22264

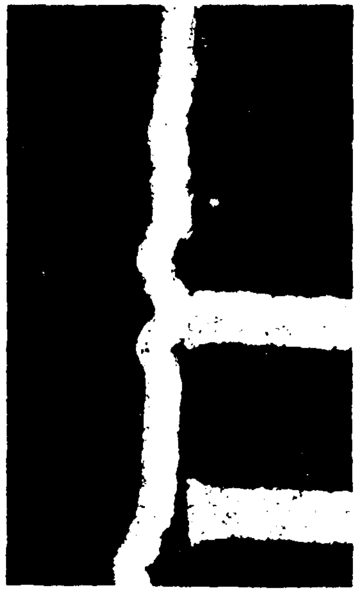
EXHIBIT 12. Test Pattern Circuit Configuration.

EXHIBIT 13. Bomb-Sight Drill Used in the Subject Drill Study Performed in This Paper.

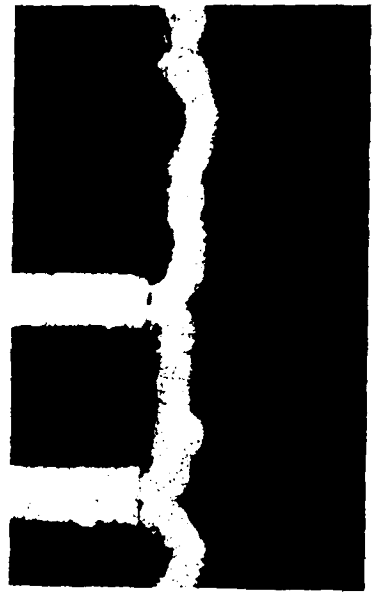
EXHIBIT 14
PRELIMINARY DRILL STUDY



5 — 40,000 RPM



4 — 30,000 RPM



3 — 20,000 RPM

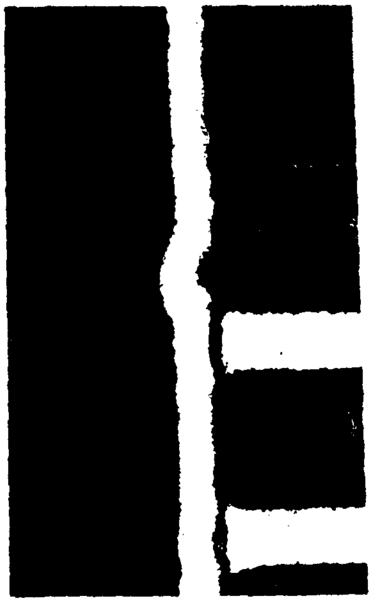
2 — 10,000 RPM

1 — 5,000 RPM

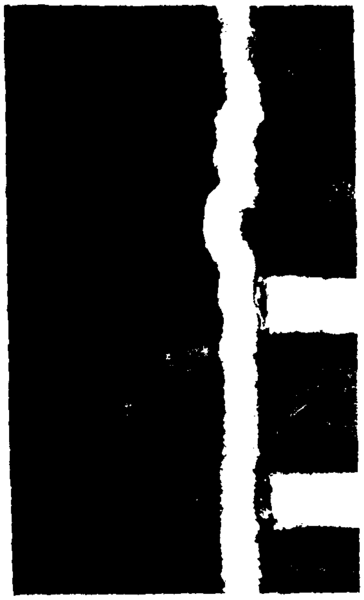
MAGNIFICATION APPROXIMATELY 200X

EXHIBIT 14

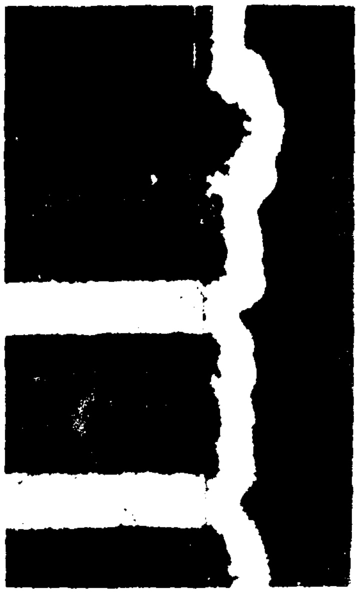
All samples were drilled in a panel made with vendor "A"'s polyimide glass material. These holes were drilled at a feed rate of approximately 20 inches per minute. No desmearing operation was performed on them.



10 – 40,000 RPM



9 – 30,000 RPM



8 – 20,000 RPM

7 – 10,000 RPM

6 – 5,000 RPM

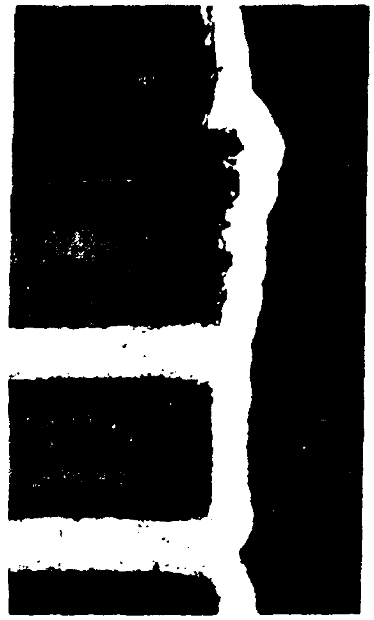
MAGNIFICATION APPROXIMATELY 200X

EXHIBIT 14

All samples were drilled in a panel made with Vendor "A"'s polyimide glass material. These holes were drilled at a feed rate of approximately 30 inches per minute. No desmearing operation was performed on them.

15 – 40,000 RPM

14 – 30,000 RPM



13 – 20,000 RPM

12 – 10,000 RPM

11 – 5,000 RPM

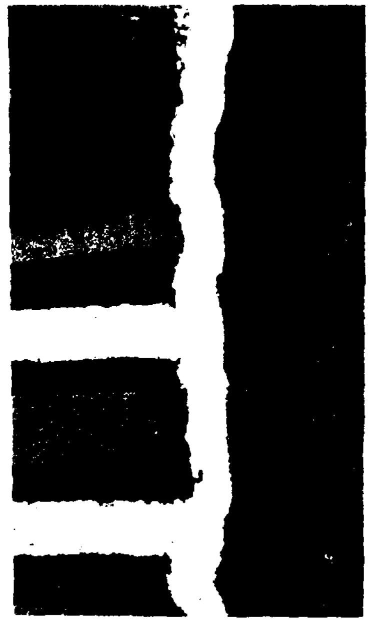
MAGNIFICATION 200X

EXHIBIT 14

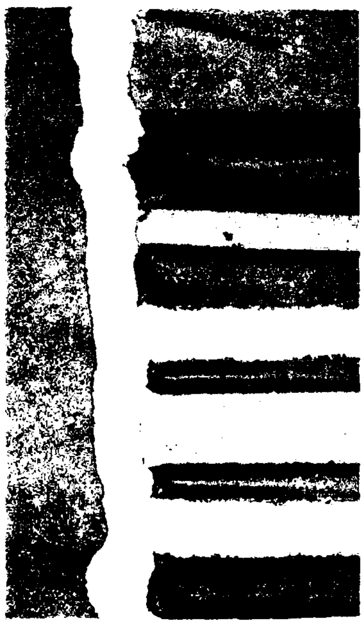
All samples were drilled in a panel made with Vendor "A"'s polyimide glass material. These holes were drilled at a feed rate of approximately 40 inches per minute. No desmearing operation was performed on them.

5-40,000 RPM

4 – 30,000 RPM



3 – 20,000 RPM



2 10,000 RPM

1 – 5,000 RPM

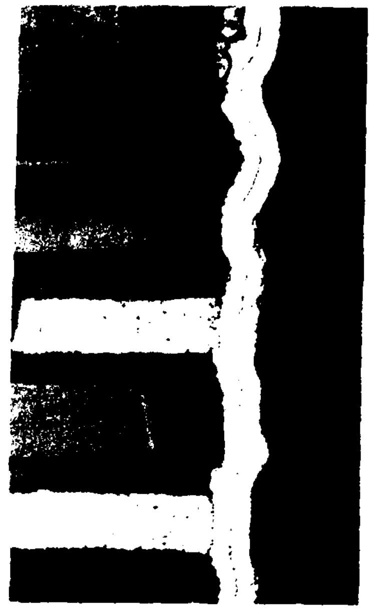
MAGNIFICATION APPROXIMATELY 200X

EXHIBIT 14

All samples were drilled in a panel made with Vendor "F"'s polyimide glass material. These holes were drilled at a feed rate of approximately 20 inches per minute. The holes were desmeared in an oxygen/freon gas plasma at 200 watts power and a total pressure of .5 for 6 minutes.

10 – 40,000 RPM

9 – 30,000 RPM



8 – 20,000 RPM

7 – 10,000 RPM

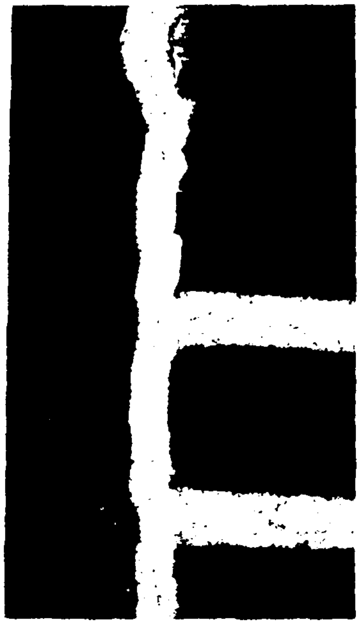
6 – 5,000 RPM

MAGNIFICATION APPROXIMATELY 200X

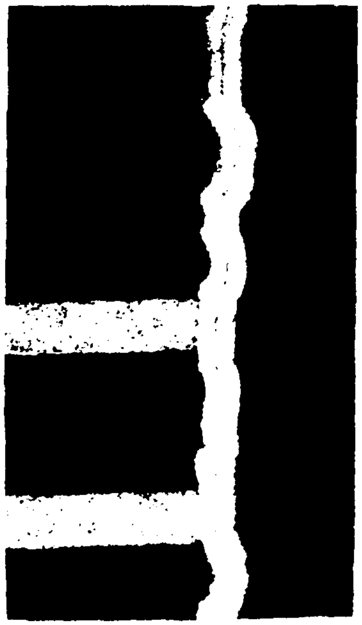
EXHIBIT 14

All samples were dilled in a panel made with Vendor "F"'s polyimide glass material. These holes were drilled at a feed rate of approximately 30 inches per minute. The holes were desmeared in oxygen freon gas plasma at 200 watts power and total pressure of .5 torr for 6 minutes.

15 – 40,000 RPM

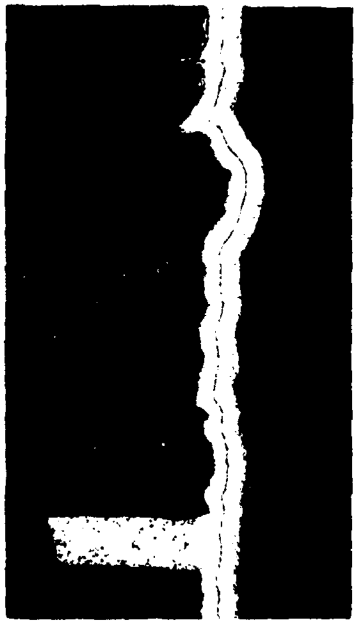


14 – 30,000 RPM



13 – 20,000 RPM

12 – 10,000 RPM



11 – 5,000 RPM

MAGNIFICATION APPROXIMATELY 200X

EXHIBIT 14

All samples were drilled in a panel made with Vendor "F"'s polyimide glass material. These holes were drilled at a feed rate of approximately 40 inches per minute. The holes were desmeared in an oxygen/freon gas plasma at 200 watts power and a total pressure of .5 torr for 6 minutes.

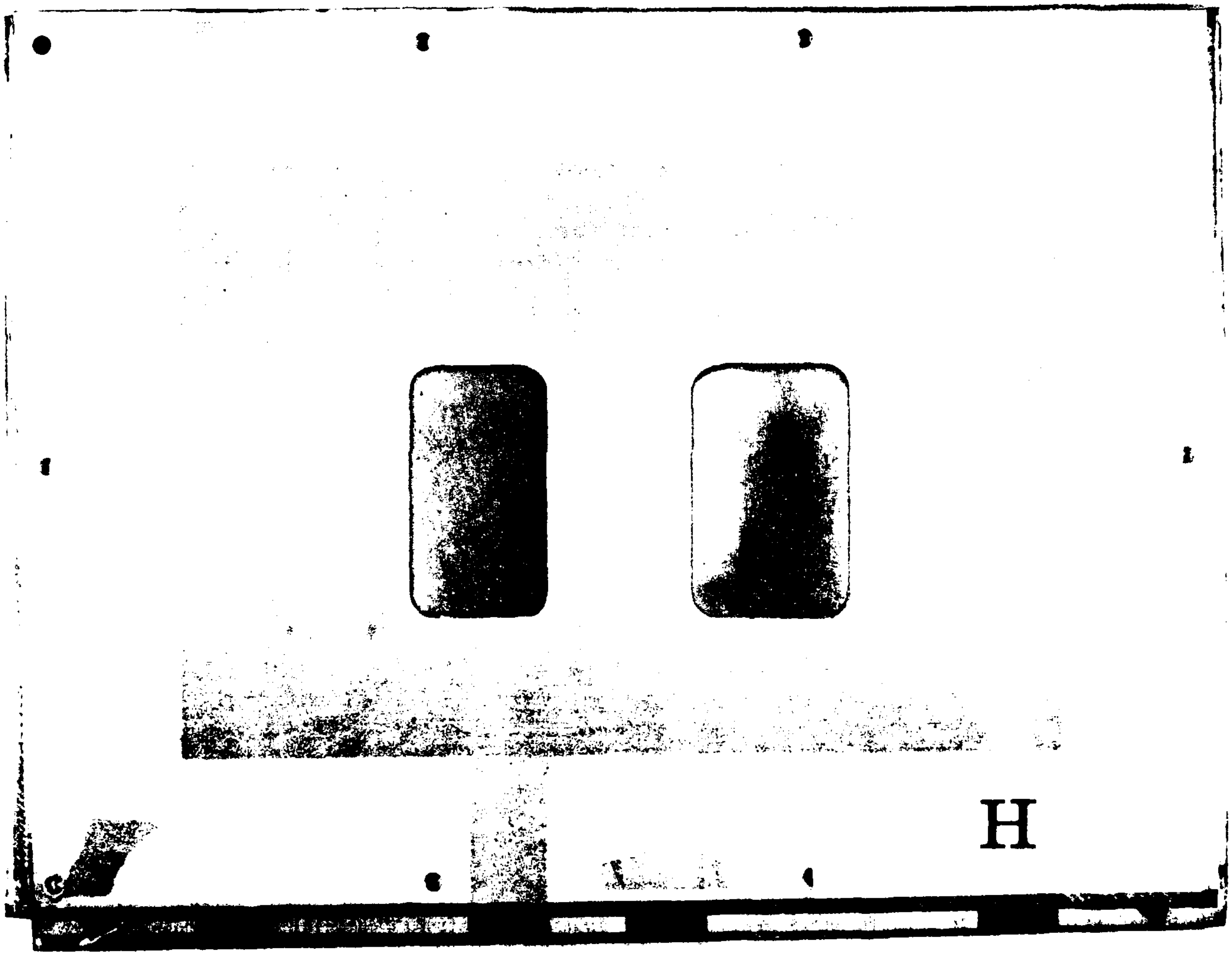


EXHIBIT 15. Test panel laminated at 600 psi pressure/etched bleeder channels.
Note: Gross air entrapment in laminate.

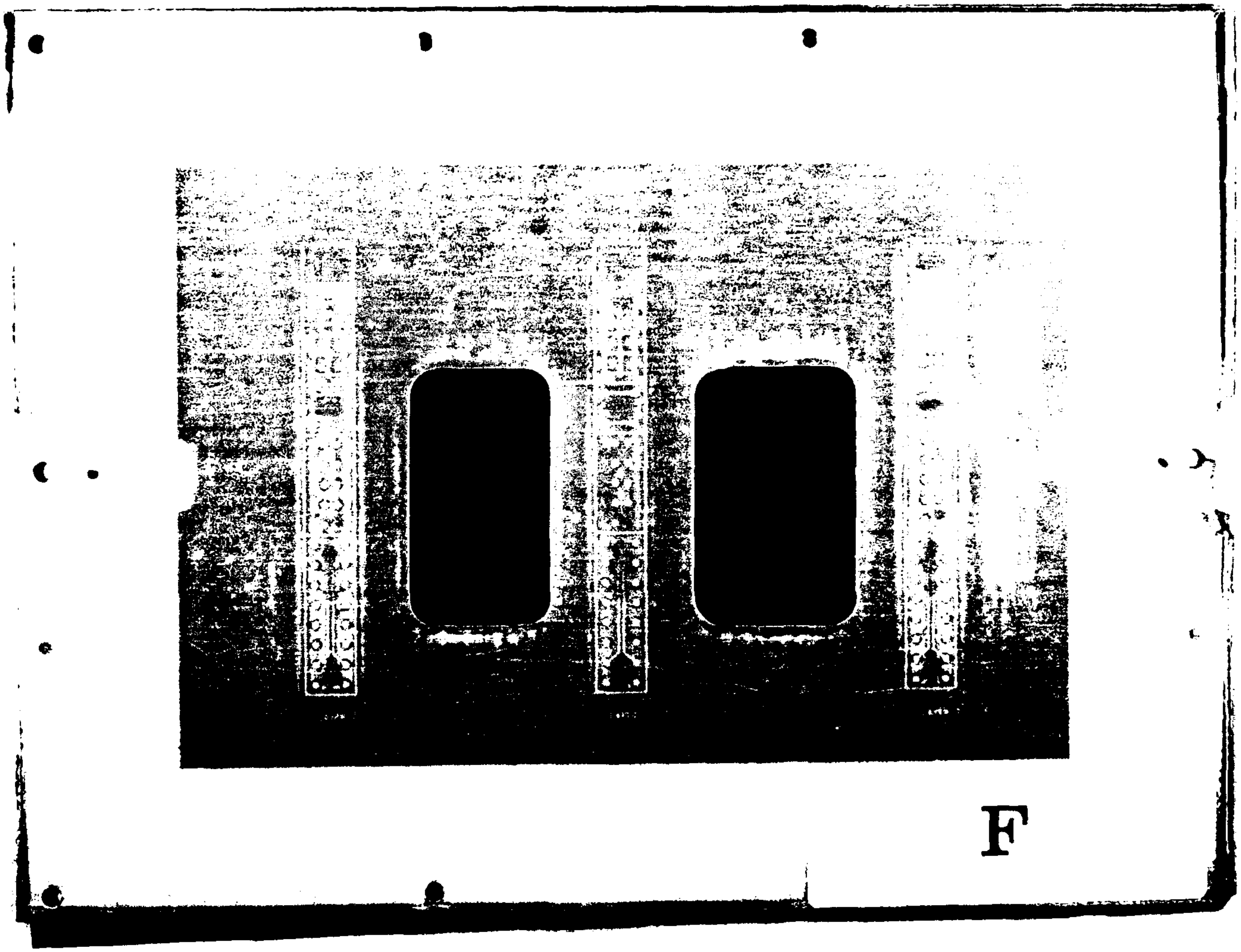


EXHIBIT 16. Test panel laminated at 600 psi using cut air bleeder channels.
Note: Small amount of air entrapment but unacceptable.

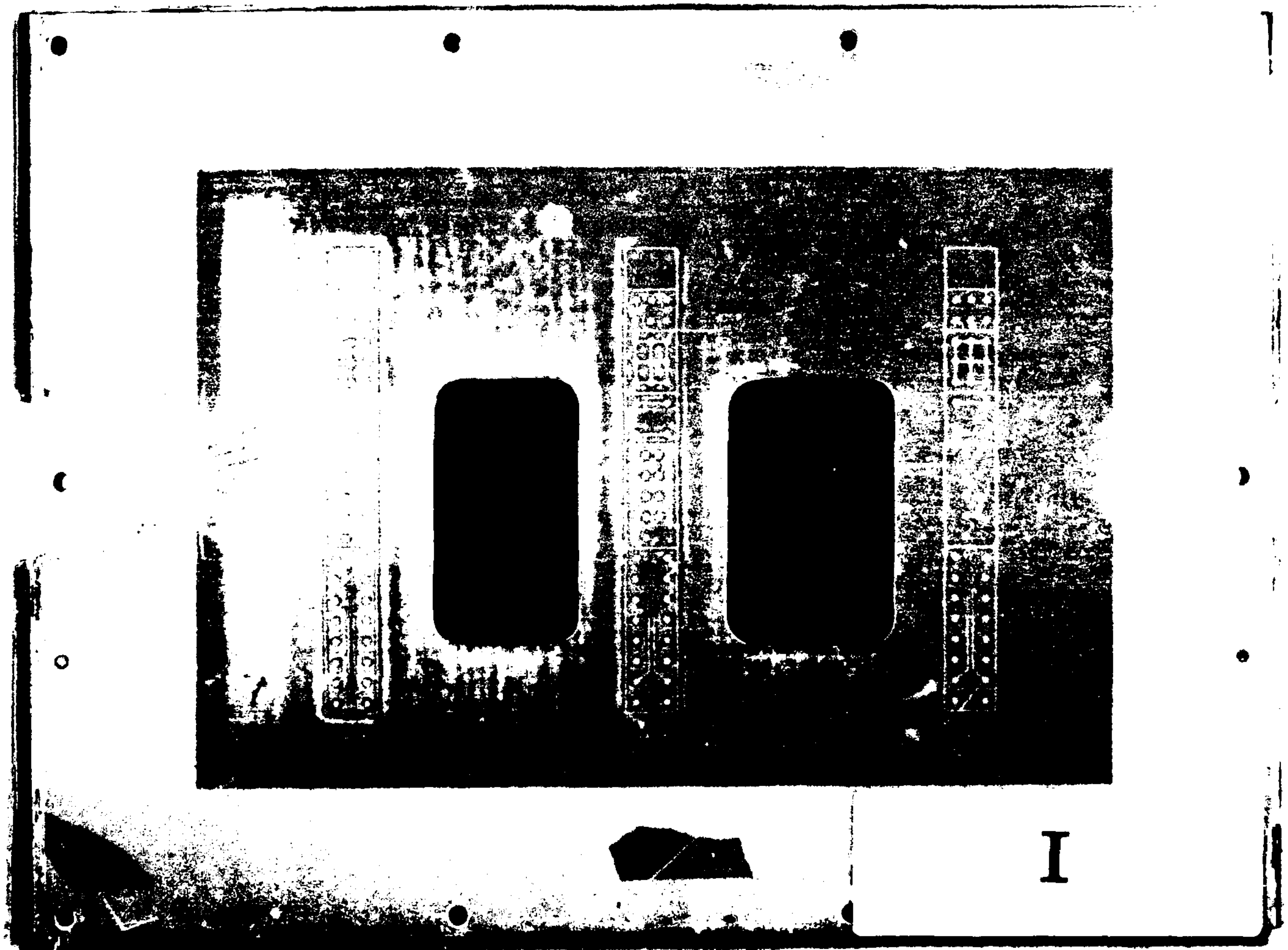


EXHIBIT 17. Test panel laminated at 600 psi with cut air bleeder channels.
Note: Gross air in one side of panel indicates non-parallel press platens.

EXHIBIT 18
LAMINATION USING
INCREASED PRESSURE INCREMENTS

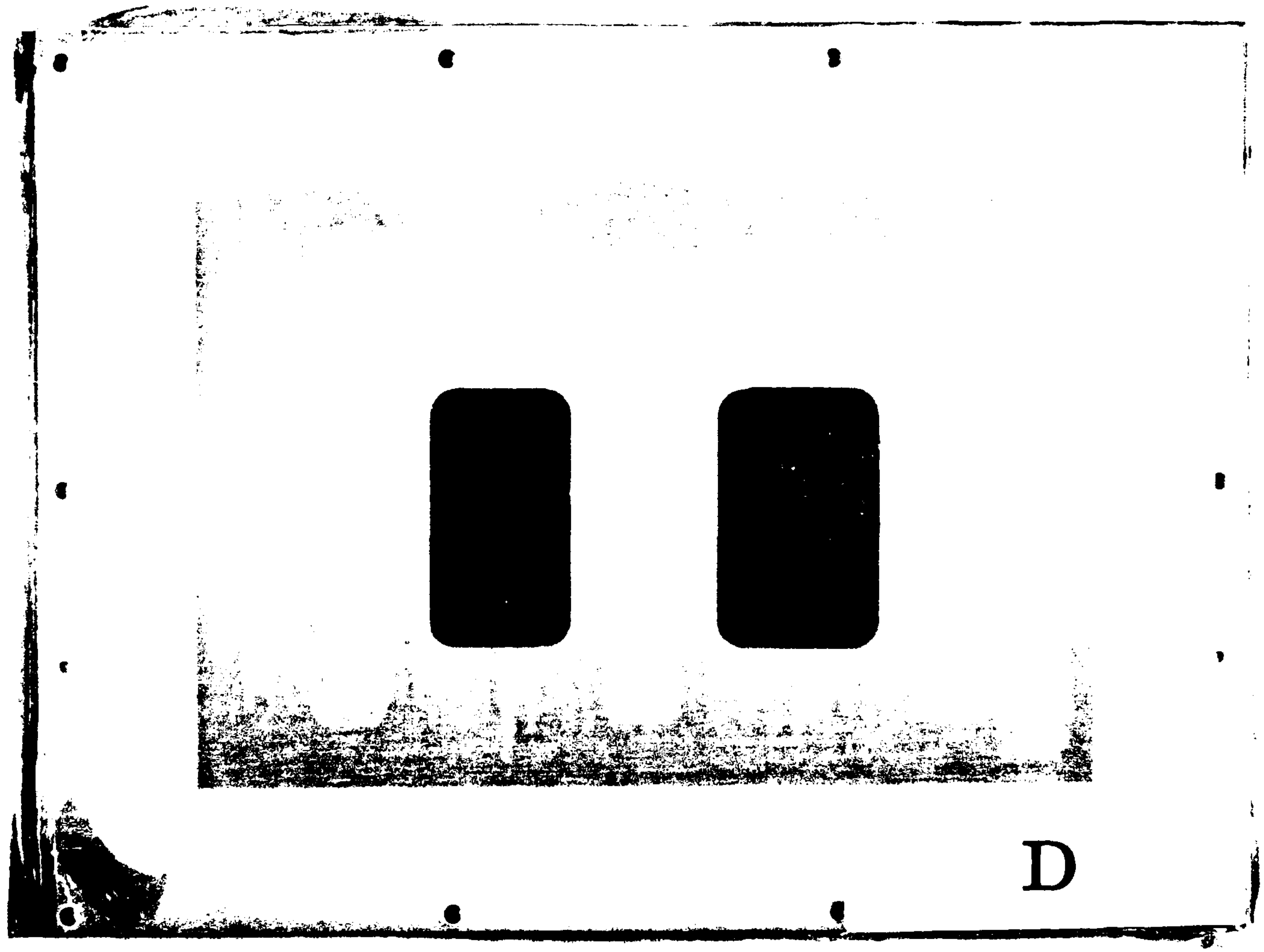


EXHIBIT 18
Test panel laminated at 400 psi pressure.
Note: Gross amounts of trapped air in the laminate.

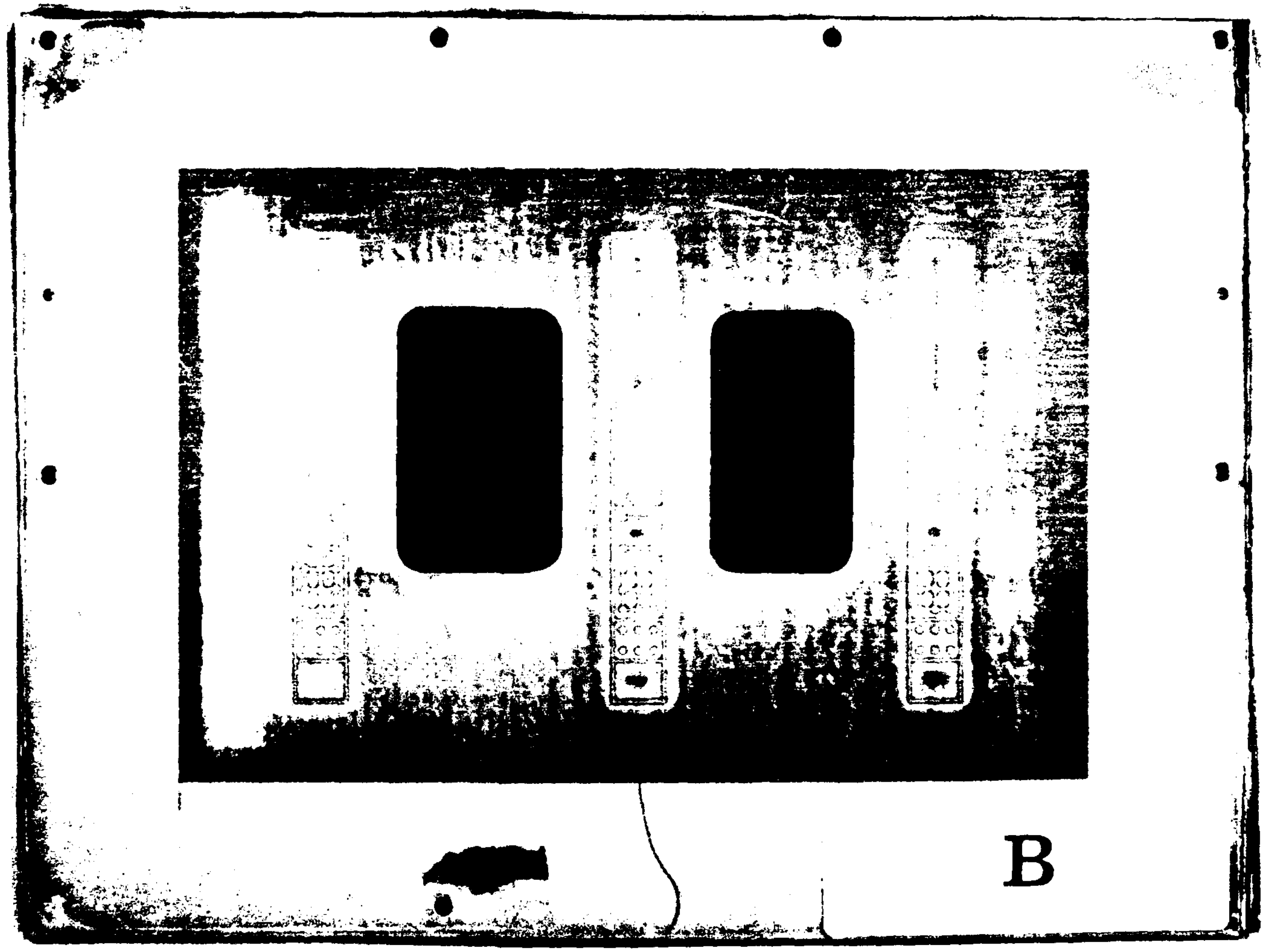


EXHIBIT 18
Test panel laminated at 500 psi pressure.
Note: Gross amounts of trapped air in laminate.

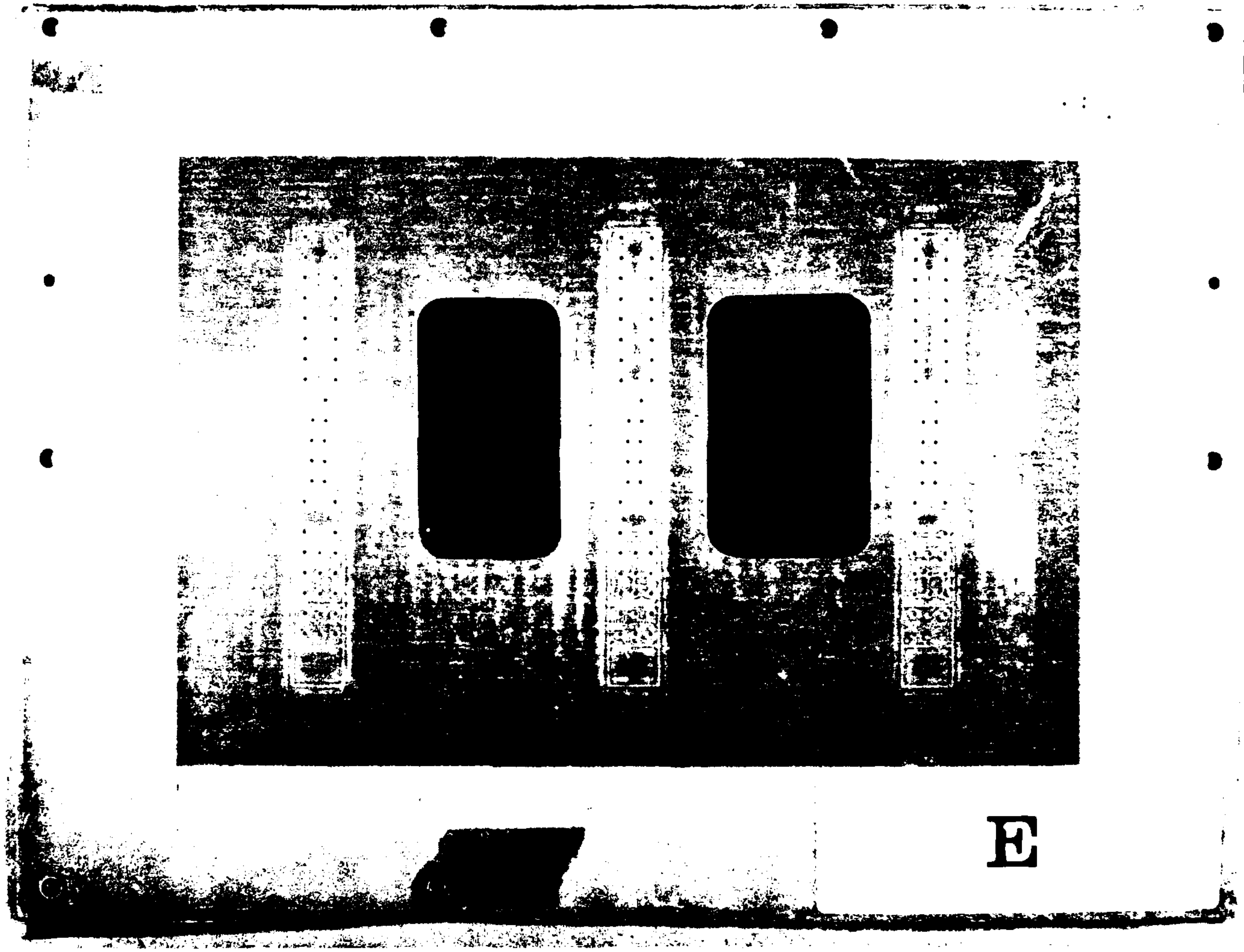


EXHIBIT 18

Test panel laminated at 600 psi pressure.
Note: Gross amounts of trapped air in the laminate.

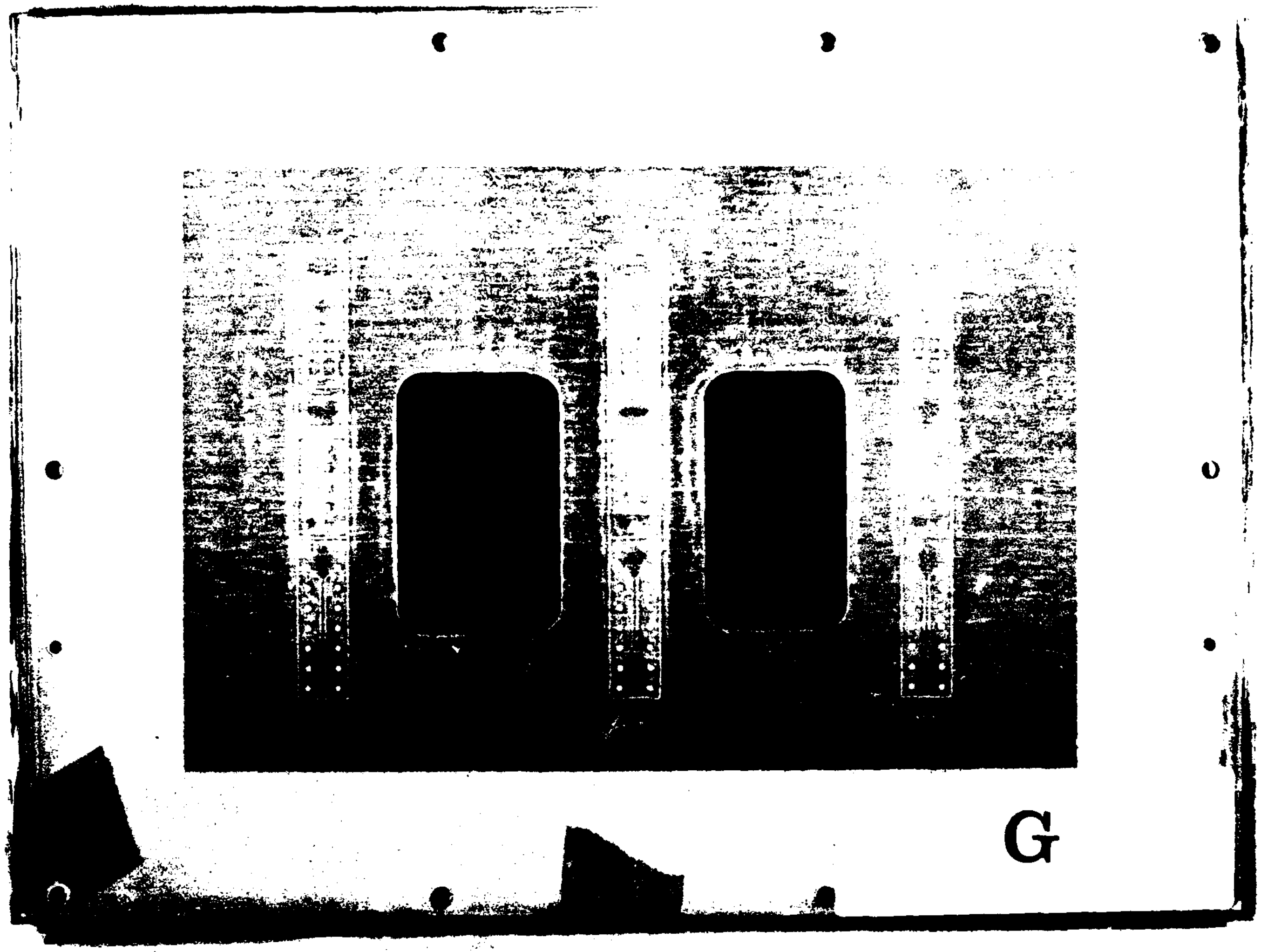


EXHIBIT 18
Test panel laminated at 700 psi pressure.
Note: Traces of trapped air around circuits and window.

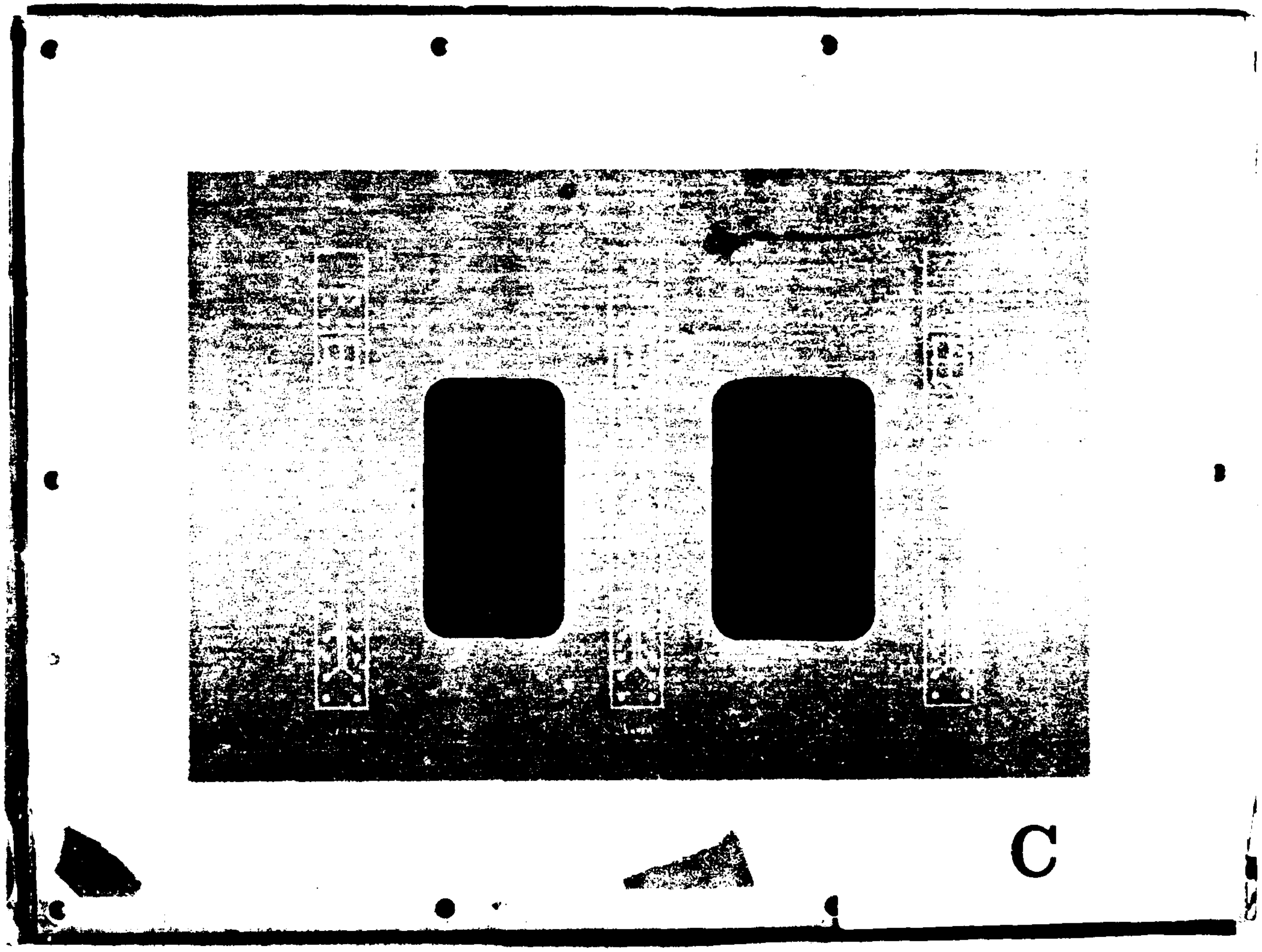


EXHIBIT 18
Test panel laminated at 800 psi.
Note: All air in laminate has been eliminated.

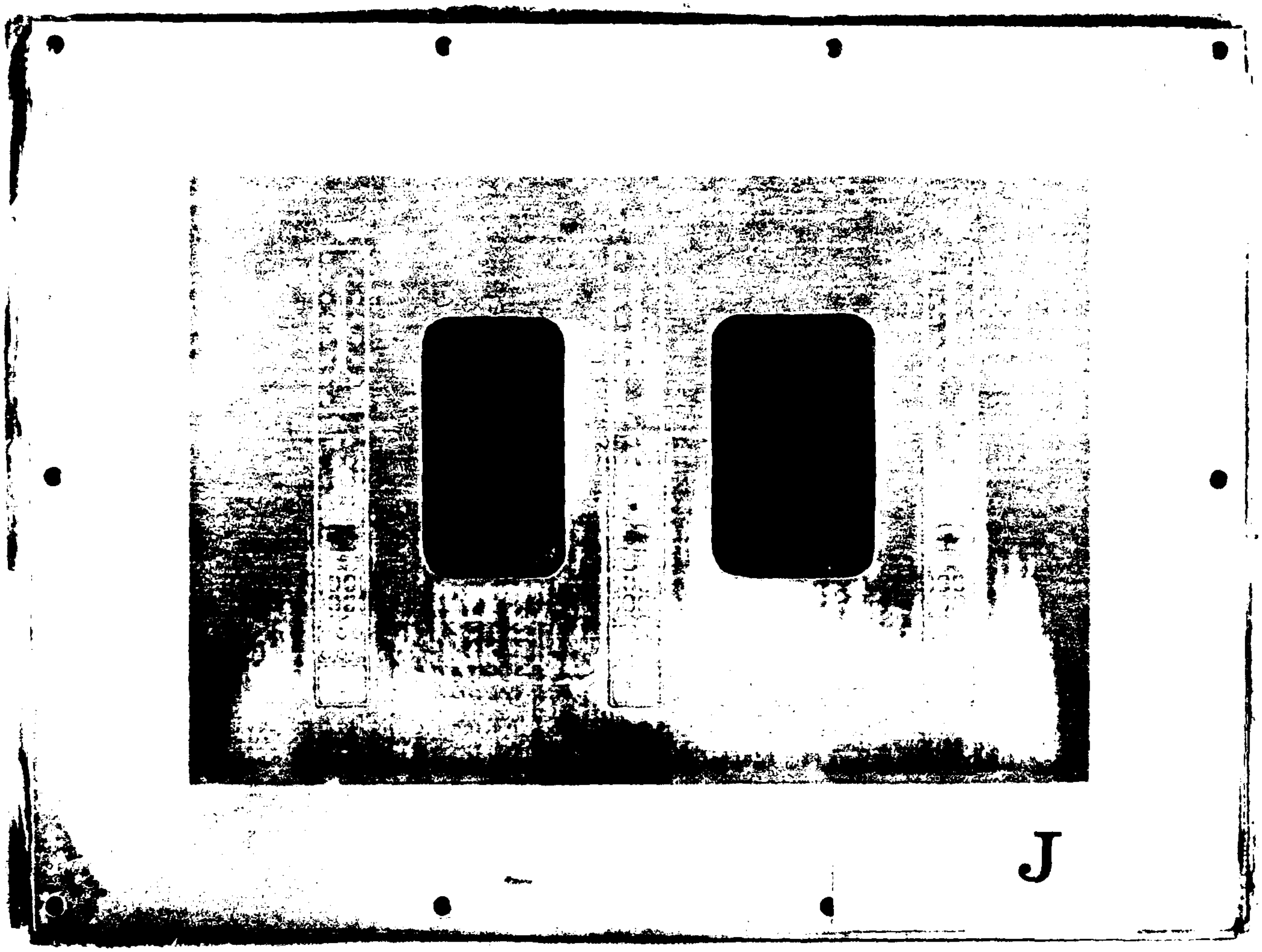


EXHIBIT 18

Test panel laminated at 800 psi pressure in press
with non-parallel platens.
Note: Gross air entrapment on one side of platen.

EXHIBIT 19

TREATMENT OF KAPTON SURFACE WITH
DRY GAS PLASMA

EQUIPMENT:

TECHNIQUES WEST - 38 INCH DIA. CHAMBER

OPERATING PARAMETERS

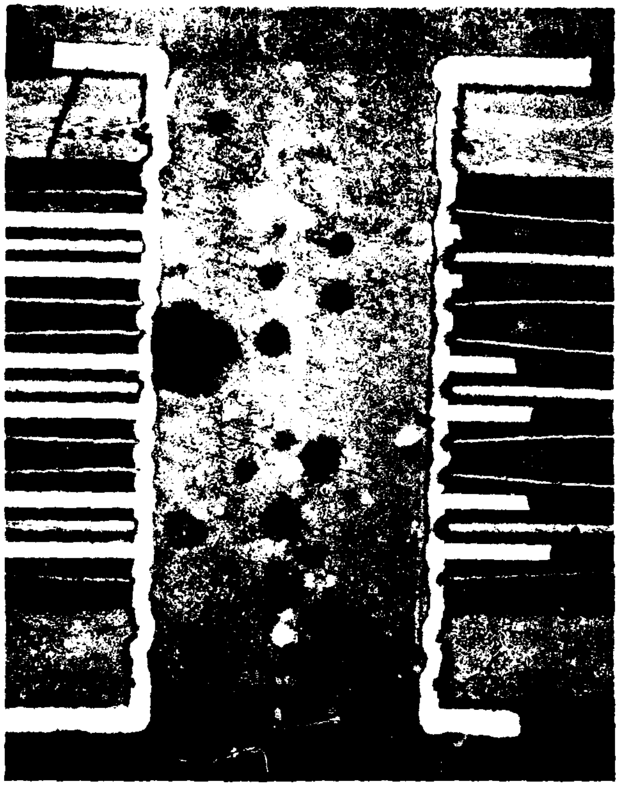
GAS - OXYGEN

POWER - 2000 WATTS

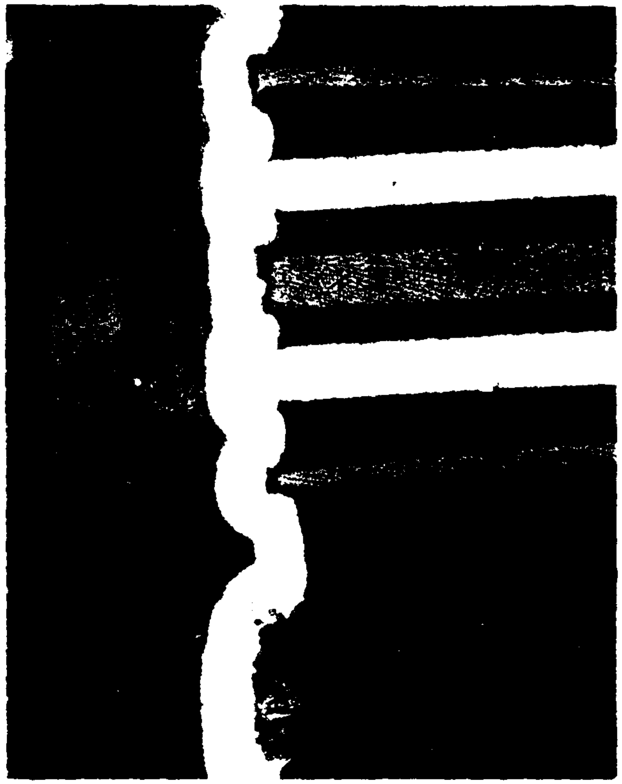
PRESSURE - 0.2 TORR

CYCLE TIME - VARIABLE

AVERAGE PEEL VALUE	CYCLE TIME	FAILURE MODE
4.4 LBS	0	ADHESIVE
5.7 LBS	30 SECONDS	ADHESIVE
9.2 LBS	1 MINUTE	ADHESIVE
19.0 LBS	3 MINUTES	PARENT MATERIAL



Thermal Shock



Thermal Shock

MAGNIFICATION APPROXIMATELY 200X

EXHIBIT 20

Thermal shock test. This is the third panel fabricated. The drilling parameters were 20,000 rpm/30 inches per minute. The plasma desmear operation was 200 watts at 0.5 torr total pressure for 10 minutes. This photomicrograph illustrates the poor registration of inner circuit layers mentioned earlier.

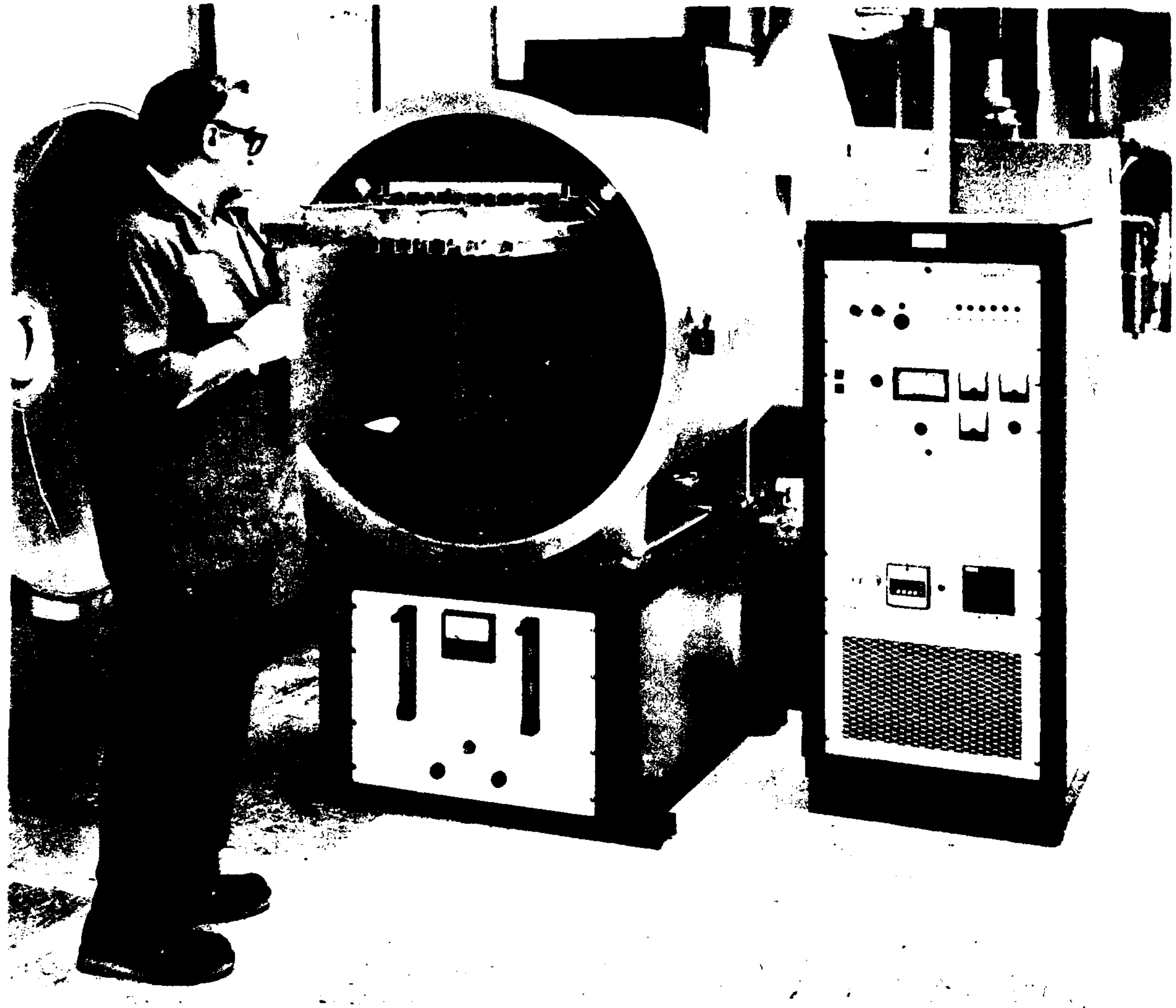


EXHIBIT 21. Techniques West Gas Plasma Reactor Used to Remove Drill Smear in an 8-Layer Rigid-Flex Printed Wiring Cable.

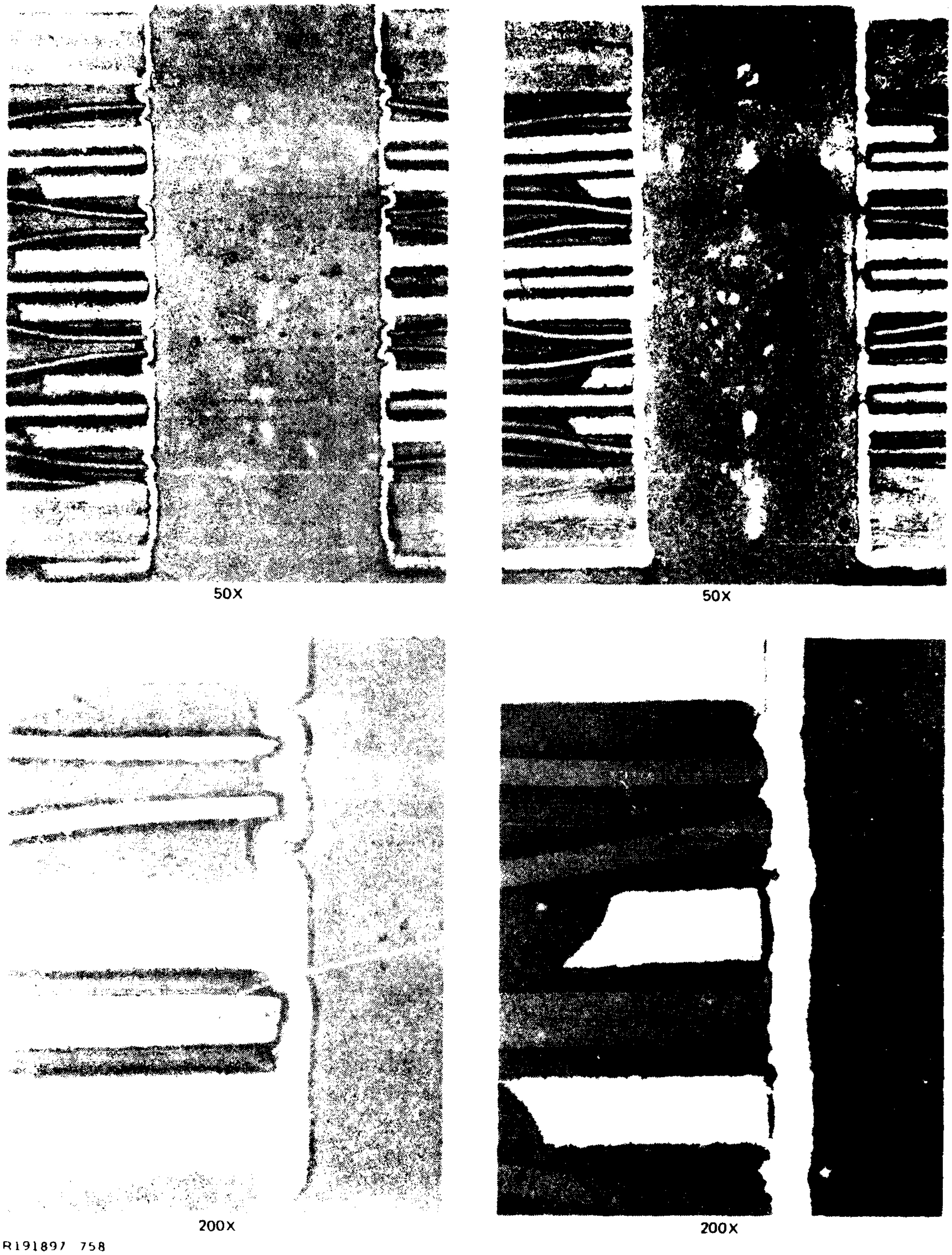


EXHIBIT 22

Plasma Smear Removal. These photos show the result of removing the drill smear from an 8-layer Rigid-Flex Printed Wiring Cable. Photos on right exhibit inadequate removal, those at left exhibit too much etch-back.

EXHIBIT 23

Data sheets of tests performed at Delsen Labs, Truesdail Labs, General Dynamics, and Peabody Testing Lab.

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TEST REPORT

In account with	Date	Page
GENERAL DYNAMICS P.O. Box 2507 Pomona, CA. 91766	4/28/78	1 of 28 Pages
	W O No T 15159	P O No P0083165
	Identification As noted	Shipper No number

SPECIFICATION: MIL-P-55617A

ELECTRIC STRENGTH
Conditioned: D48/50 + D½/23
By The Short Time Method
500 Volts/Second Rise Time
Using 2.0 Inch Electrodes in Oil

Mfg. Tech. M-24-6-713, Item #2
TEST METHOD : Paragraph 4.7.2.7

SPECIMEN	THICKNESS INCHES	BREAKDOWN VOLTAGE KV	DIELECTRIC STRENGTH VOLTS/MIL
Supplier "F"			
111ES			
1	0.0111	12.3	1,110
2	0.0097	12.3	1,270
3	0.0106	11.9	1,120
211ES			
1	0.0109	11.6	1,060
2	0.0114	12.9	1,130
3	0.0114	11.9	1,040
		AVERAGE:	1,120
		MINIMUM REQUIREMENT:	750

RESEARCH AND DEVELOPMENT TESTING

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ELECTRIC STRENGTH (continued)

SPECIMEN	THICKNESS INCHES	BREAKDOWN VOLTAGE KV	DIELECTRIC STRENGTH VOLTS/MIL
Supplier "A"			
111ES			
1	0.0108	13.3	1,230
2	0.0103	8.9	860
3	0.0108	12.9	1,190
211ES			
1	0.0107	13.6	1,270
2	0.0099	11.6	1,170
3	0.0102	13.6	1,330
		AVERAGE:	1,180
		MINIMUM REQUIREMENT:	750

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W.O. No.	Page			
T 15159	Page	3	of 28	Pages

DIELECTRIC CONSTANT AND DISSIPATION FACTOR
Tested as Received at Room Temperature

Mfg. Tech. M-24-6-713, Item #3 and #4
TEST METHOD: ASTM D-150
TEST FREQUENCY: 1.0 Megahertz

SPECIMEN	THICKNESS MILS	DISSIPATION FACTOR	DIELECTRIC CONSTANT
Supplier "F"			
A12-1	9.95	0.016	4.44
2	9.97	0.016	4.42
3	9.82	0.016	4.43
A22-1	10.15	0.015	4.42
2	10.02	0.014	4.38
3	10.01	0.015	4.43
	AVERAGE:	0.015	AVERAGE: 4.42
	MAXIMUM REQUIREMENT:	0.025	4.8
Supplier "A"			
12-1	9.73	0.018	4.65
2	9.82	0.020	4.64
3	9.80	0.016	4.69
22-1	9.71	0.015	4.46
2	9.58	0.014	4.56
3	9.58	0.017	4.58
	AVERAGE:	0.017	AVERAGE: 4.60
	MAXIMUM REQUIREMENT:	0.025	4.8

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COEFFICIENT OF THERMAL EXPANSION

Mfg. Tech. M-24-6-713, Item #5

TEST METHOD: MIL-P-55617B, paragraph 4.7.13;
IPC-TM-650, Method 2.4.24.

SPECIMEN	THICKNESS INCHES	COEFFICIENT OF THERMAL EXPANSION INCH/INCH/°C	GLASS TRANSITION TEMPERATURE °C
Supplier "F"			
1	0.085	69.6×10^{-6}	209
2	0.084	67.3×10^{-6}	217
3	0.086	70.3×10^{-6}	209
Supplier "A"			
1	0.095	64.2×10^{-6}	212
2	0.093	55.3×10^{-6}	212
3	0.095	59.3×10^{-6}	206

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W.O No. T 15159

PEEL STRENGTH AT ELEVATED TEMPERATURE

Tested at 150°C after Conditioning for 1 Hour at 150°C

Mfg. Tech. M-24-6-713, Item #6

SPECIMEN		WIDTH INCHES	MINIMUM LOAD GRAMS	PEEL STRENGTH POUNDS/INCH OF WIDTH
Supplier "F"				
16-3	Parallel			
A		0.127	244	4.2
B		0.128	240	4.1
C		0.128	243	4.2
D		0.127	225	3.9
			AVERAGE:	4.1
16-5	Perpendicular			
A		0.127	235	4.1
B		0.127	224	3.9
C		0.125	234	4.1
D		0.127	254	4.4
			AVERAGE:	4.1
18-3	Parallel			
A		0.126	232	4.1
B		0.126	231	4.0
C		0.126	224	3.9
D		0.127	241	4.2
			AVERAGE:	4.0
18-4	Perpendicular			
A		0.127	250	4.3
B		0.127	240	4.2
C		0.127	226	3.9
D		0.126	251	4.4
			AVERAGE:	4.2

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PEEL STRENGTH AT ELEVATED TEMPERATURE (continued)

SPECIMEN	WIDTH INCHES	MINIMUM LOAD GRAMS	PEEL STRENGTH POUNDS/INCH OF WIDTH
Supplier "F"			
28-1 Parallel			
A	0.124	201	3.6
B	0.125	225	4.0
C	0.124	224	4.0
D	0.127	260	4.5
		AVERAGE:	4.0
-28-3 Parallel			
A	0.125	460	4.1
B	0.126	244	4.3
C	0.125	238	4.2
D	0.127	245	4.2
		AVERAGE:	4.2
28-4 Perpendicular			
A	0.124	219	3.9
B	0.125	205	3.6
C	0.124	240	4.3
D	0.126	214	3.7
		AVERAGE:	3.9
28-5 Perpendicular			
A	0.123	242	4.3
B	0.125	231	4.1
C	0.125	218	3.8
D	0.127	240	4.2
		AVERAGE:	4.1

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PEEL STRENGTH AT ELEVATED TEMPERATURE (continued)

SPECIMEN	WIDTH INCHES	MINIMUM LOAD GRAMS	PEEL STRENGTH POUNDS/INCH OF WIDTH
Supplier "A"			
17-1 Parallel			
A	0.123	262	4.7
B	0.124	249	4.6
C	0.124	265	4.7
D	0.126	279	4.9
		AVERAGE:	4.7
17-6 Perpendicular			
A	0.126	273	4.8
B	0.124	265	4.7
C	0.124	257	4.6
D	0.125	279	4.9
		AVERAGE:	4.8
18-1 Parallel			
A	0.127	257	4.5
B	0.126	258	4.5
C	0.126	264	4.6
D	0.125	271	4.8
		AVERAGE:	4.6
18-6 Perpendicular			
A	0.127	275	4.8
B	0.126	262	4.6
C	0.126	247	4.3
D	0.126	267	4.7
		AVERAGE:	4.6

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PEEL STRENGTH AT ELEVATED TEMPERATURE (continued)

SPECIMEN	WIDTH INCHES	MINIMUM LOAD GRAMS	PEEL STRENGTH POUNDS/INCH OF WIDTH
Supplier "A"			
28-2 Parallel			
A	0.125	256	4.5
B	0.126	255	4.5
C	0.125	251	4.4
D	0.128	262	4.5
			AVERAGE: 4.5
28-3 Parallel			
A	0.126	241	4.2
B	0.126	250	4.4
C	0.126	246	4.3
D	0.128	283	4.9
			AVERAGE: 4.5
28-4 Perpendicular			
A	0.125	217	3.8
B	0.125	218	3.8
C	0.125	223	3.9
D	0.127	264	4.6
			AVERAGE: 4.0
28-5 Perpendicular			
A	0.125	227	4.0
B	0.126	211	3.7
C	0.126	226	4.0
D	0.128	229	3.9
			AVERAGE: 3.9

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VOLUME AND SURFACE RESISTIVITY

Mfg. Tech. M-24-6-713, Items #1 and #7

SPECIMEN	CONDITION	THICKNESS INCHES	SURFACE RESISTIVITY MEGOHMS	VOLUME RESISTIVITY MEGOHM-CM
Supplier "A"				
1-12				
1	1	0.0103	1.1×10^5	5.9×10^6
2	1	0.0100	9.9×10^4	2.8×10^6
3	1	0.0095	5.1×10^4	2.1×10^6
4	1	0.0100	1.3×10^4	1.1×10^6
1-12				
1	2	0.0103	3.5×10^4	2.8×10^7
2	2	0.0100	7.6×10^4	2.0×10^7
3	2	0.0095	1.8×10^5	2.6×10^7
4	2	0.0100	3.1×10^4	1.7×10^7
Supplier "F"				
2-12				
1	1	0.0090	3.2×10^4	5.7×10^7
2	1	0.0103	2.8×10^5	5.9×10^7
3	1	0.0102	2.3×10^4	5.6×10^7
4	1	0.0113	1.9×10^4	3.2×10^7
2-12				
1	2	0.0090	4.5×10^4	3.4×10^7
2	2	0.0103	1.2×10^5	6.5×10^7
3	2	0.0102	1.3×10^5	3.8×10^7
4	2	0.0113	6.1×10^4	5.2×10^7

1=Tested at 35°C and 90% Relative Humidity after conditioning C-96/35/90.

2=Tested at 200°C after conditioning E-24/200.

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ARC RESISTANCE

Mfg. Tech. M-24-6-713, Item #8
TEST METHOD: MIL-P-55617B, paragraph 4.7.2.9
CONDITIONING: D-48/50 + D-1/2 /23

SPECIMEN	THICKNESS INCHES	ARC RESISTANCE TIME SECONDS	REMARKS
Supplier "A"			
111AR			
1	0.020	123	Carbonization
2	0.020	125	Carbonization
3	0.020	123	Carbonization
4	0.020	125	Carbonization
5	0.020	123	Carbonization
211AR			
1	0.021	125	Carbonization
2	0.020	125	Carbonization
3	0.020	121	Carbonization
4	0.020	122	Carbonization
5	0.020	122	Carbonization
	AVERAGE:	123	
	MINIMUM REQUIREMENT:	120	

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ARC RESISTANCE (continued)

SPECIMEN	THICKNESS INCHES	ARC RESISTANCE TIME SECONDS	REMARKS
Supplier "F" 111AR			
1	0.021	125	Carbonization
2	0.021	124	Carbonization
3	0.021	125	Carbonization
4	*		
5	0.022	125	Carbonization
211AR			
1	0.022	124	Carbonization
2	0.022	125	Carbonization
3	0.021	124	Carbonization
4	0.021	125	Carbonization
5	0.021	128	Carbonization
		AVERAGE: 125	
		MINIMUM REQUIREMENT: 120	

*Unable to locate

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FLEXURAL STRENGTH AND MODULUS

Tested at Room Temperature
Test Rate: 0.04 Inch/Minute
Span: 1.500 Inches

Mfg. Tech. M-24-6-713, Items #9 and #13
TEST METHOD: ASTM D-790

SPECIMEN	THICKNESS INCHES	WIDTH INCHES	MAXIMUM LOAD POUNDS	TYPE OF FAILURE	FLEXURAL STRENGTH PSI	FLEXURAL MODULUS PSIx10 6
Supplier "F" - Parallel						
1	0.078	1.001	177	T	65,400	2.8
2	0.083	1.002	194	T	63,300	2.9
				AVERAGE:	64,300	3.0
Supplier "F" - Perpendicular						
1	0.073	1.003	156	T	65,700	3.2
2	0.073	1.003	154	T	64,800	3.3
				AVERAGE:	65,300	3.3
Supplier "A" - Parallel						
1	0.095	1.001	278	T	69,200	3.8
2	0.094	1.001	270	T	68,700	3.8
				AVERAGE:	69,000	3.8
Supplier "A" - Perpendicular						
1	0.093	1.004	206	T	53,400	3.3
2	0.095	1.002	197	T	49,000	3.3
				AVERAGE:	51,200	3.3

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FLEXURAL STRENGTH AND MODULUS
WEATHER RESISTANCE

Tested at Room Temperature
After Conditioning for 200 Hours per ASTM G-23
Test Rate: 0.04 Inch/Minute
Span: 1.500 Inches

Mfg. Tech. M-24-6-713, Item #12

TEST METHOD: ASTM D-790

SPECIMEN	THICKNESS INCHES	WIDTH INCHES	MAXIMUM LOAD POUNDS	TYPE OF FAILURE	FLEXURAL STRENGTH PSI	FLEXURAL MODULUS PSI X 10^6
Supplier "A"						
1	0.0962	0.998	252	T	61,400	3.5
2	0.0957	0.999	253	T	62,200	3.6
3	0.0961	0.999	250	T	61,000	3.6
4	0.0963	0.999	244	T	59,300	3.5
				AVERAGE:	61,000	3.6
Supplier "F"						
1	0.0828	0.999	171.9	T	56,500	2.7
2	0.0827	1.000	160.8	T	52,900	2.6
3	0.0814	1.000	162.1	T	55,000	2.8
4	0.0842	0.999	173.7	T	55,200	2.5
				AVERAGE:	54,900	2.7

T=Tension Failure

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VERTICAL BURN TEST FOR CLASSIFYING MATERIALS 94V-0, 94V-1, or 94V-2

Mfg. Tech. M-24-6-713, Item #14

TEST METHOD: UL-94 (3.6 - 3.15)

SPECIMEN	THICKNESS INCHES	FLAME TIME AFTER 1ST APPLICATION SECONDS	FLAME TIME AFTER 2ND APPLICATION SECONDS	DURATION OF FLAMING AND GLOWING AFTER 2ND APPLICATION SECONDS	SPECIMEN BURNS TO CLAMP	IGNITION OF COTTON BY DRIPS
Supplier "F"						
2-10						
1	0.076	0.8	15.5	15.7	NO	ND
2	0.077	11.3	12.6	12.8	NO	ND
3	0.074	7.2	12.5	12.7	NO	ND
4	0.082	5.6	14.8	15.2	NO	ND
5	0.081	0.7	18.6	18.6	NO	ND
	TOTAL:	25.6	74.0	75.0		

CLASSIFICATION OF MATERIALS: 94V-1

SPECIMEN	THICKNESS INCHES	FLAME TIME AFTER 1ST APPLICATION SECONDS	FLAME TIME AFTER 2ND APPLICATION SECONDS	DURATION OF FLAMING AND GLOWING AFTER 2ND APPLICATION SECONDS	SPECIMEN BURNS TO CLAMP	IGNITION OF COTTON BY DRIPS
Supplier "A"						
2-10						
1	0.095	2.7	15.4	15.4	NO	ND
2	0.093	8.0	16.4	16.6	NO	ND
3	0.093	1.4	13.2	13.2	NO	ND
4	0.097	0.7	11.6	11.6	NO	ND
5	0.095	0.7	19.2	19.2	NO	ND
	TOTAL:	13.5	75.8	76.0		

CLASSIFICATION OF MATERIALS: 94V-1

ND=No drips

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EXTENT AND TIME OF BURNING OF FLEXIBLE PLASTICS

Mfg. Tech. M-24-6-713, Item #14

TEST METHOD: ASTM D-568

SPECIMEN	THICKNESS INCHES	BURN TIME SECONDS	BURN LENGTH INCHES	BURN RATE IN/SEC	APPARENT CAUSE OF EXTINGUISHMENT
Supplier "F"					
2-10					
1	0.011	13.2	3.4	N/A	Smothering
2	0.011	32.6	9.2	N/A	Smothering
3	0.011	11.5	2.4	N/A	Smothering
4	0.011	11.2	2.5	N/A	Smothering
5	0.011	12.5	2.6	N/A	Smothering
	AVERAGE:	16.2	4.0		
Supplier "A"					
2-10					
1	0.010	18.7	3.9	N/A	Smothering
2	0.010	16.9	2.4	N/A	Smothering
3	0.010	14.1	2.7	N/A	Smothering
4	0.010	32.1	6.0	N/A	Smothering
5	0.010	28.8	5.1	N/A	Smothering
	AVERAGE:	22.1	4.0		

DELSEN TESTING LABORATORIES, INC.
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THERMAL CONDUCTIVITY

Mfg. Tech. M-24-6-713, Item #15

TEST METHOD: ASTM D-2214

SPECIMEN	THICKNESS INCHES	THERMAL CONDUCTIVITY CAL-CM/SEC-CM^2-°C	THERMAL CONDUCTIVITY BTU-IN/HR-FT^3-°F
Supplier "F"	0.078	4.8×10^{-4}	1.4
Supplier "A"	0.095	5.7×10^{-4}	1.7

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ABSOLUTE MAXIMUM TEMPERATURE AND MAXIMUM CONTINUOUS TEMPERATURE
PEEL STRENGTH
RATE OF TEST: 2.0 INCHES/MINUTE

Mfg. Tech. M-24-6-713, Item #16 and #18

TEST METHOD: MIL-P-55617B, paragraph 4.7.2.4; customer instructions

SPECIMEN	CONDITIONING TEMPERATURE °F	TIME	TEST TEMPERATURE °F	PEEL STRENGTH POUNDS/INCH OF WIDTH
Supplier "F"				
16-1				
A			A	5.8
B	350	5 Min	350	3.8
C	350	5 Min	B	5.3
D	350	5 Min	B	5.7
26-5				
A			A	6.0
B	350	4 Hrs	B	8.1
C	350	4 Hrs	B	8.0
D	350	4 Hrs	350	5.7
16-2				
A			A	5.9
B	400	5 Min	400	3.6
C	400	5 Min	B	4.3
D	400	5 Min	B	5.1

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PEEL STRENGTH (continued)

SPECIMEN	CONDITIONING TEMPERATURE °F	TIME	TEST TEMPERATURE °F	PEEL STRENGTH POUNDS/INCH OF WIDTH
Supplier "F"				
18-5				
A			A	6.0
B	300	5 Min	B	*
C	300	5 Min	B	*
D	300	5 Min	300	4.2
27-3				
A			A	6.1
B	300	4 Hrs	300	4.4
C	300	4 Hrs	B	5.8
D	300	4 Hrs	B	5.3
26-1				
A			A	7.0
16-4				
A			A	6.6
26-2				
A			A	6.5
16-6				
A			A	5.7
26-4				
A			A	6.1

*NOTE: After making several attempts to peel at temperature, a value on Strip D was finally obtained. Strip B and C were too short to test at room temperature.

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(213) 245-8517

W.O. No. T 15159

PEEL STRENGTH (continued)

SPECIMEN	CONDITIONING TEMPERATURE °F	TIME	TEST TEMPERATURE °F	PEEL STRENGTH POUNDS/INCH OF WIDTH
Supplier "A"				
16-2				
A			A	7.6
B	350	5 Min	350	4.4
C	350	5 Min	B	7.2
D	350	5 Min	B	7.5
26-5				
A			A	7.6
B	350	4 Hrs	350	5.6
C	350	4 Hrs	B	7.6
D	350	4 Hrs	B	7.8
16-4				
A			A	7.6
B	400	5 Min	400	**
C	400	5 Min	B	7.1
D	400	5 Min	B	5.9
17-3				
A			A	6.8
B	300	5 Min	300	4.5
C	300	5 Min	B	8.4
D	300	5 Min	B	8.4
28-1				
A			A	6.2
B	300	4 Hrs	300	4.8
C	300	4 Hrs	B	5.9
D	300	4 Hrs	B	6.9

**NOTE: Due to extreme brittleness, this strip could not be peeled at temperature.

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PEEL STRENGTH (continued)

SPECIMEN	CONDITIONING TEMPERATURE °F	TIME	TEST TEMPERATURE °F	PEEL STRENGTH POUNDS/INCH OF WIDTH
Supplier "A"				
26-2 A			A	7.7
16-5 A			A	7.8
26-3 A			A	7.2
17-2 A			A	7.6
26-4 A			A	7.3

Legend: A= Tested as received at room temperature

B= Tested at room temperature after conditioning at noted temperature and duration.

DELSEN TESTING LABORATORIES, INC.
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ABSOLUTE MAXIMUM TEMPERATURE AND MAXIMUM CONTINUOUS TEMPERATURE
DIELECTRIC STRENGTH
By The Short Time Method
Using 2.00 Inch Electrodes in Oil

Mfg. Tech. M-24-6-713, Item #16 and #18
TEST METHOD: ASTM D-149

CONDITIONING: Tested at room temperature after conditioning five minutes at 350°F

SPECIMEN	THICKNESS INCHES	BREAKDOWN VOLTAGE KV	DIELECTRIC STRENGTH VOLTS/MIL
Supplier "A"			
1-3-1	0.0088	12.7	1,440
2-3-1	0.0093	12.3	1,320
1-10-1	0.0103	13.6	1,320
		AVERAGE:	1,360
Supplier "F"			
3-1	0.0111	12.7	1,140
1-10-1	0.0108	13.1	1,210
2-3-1	0.0108	12.9	1,190
		AVERAGE:	1,180

CONDITIONING: Tested at room temperature after conditioning five minutes at 400°F

SPECIMEN	THICKNESS INCHES	BREAKDOWN VOLTAGE KV	DIELECTRIC STRENGTH VOLTS/MIL
Supplier "A"			
1-3-3	0.0110	13.4	1,220
2-3-3	0.0095	13.1	1,380
1-10-3	0.0098	13.5	1,380
		AVERAGE:	1,330
Supplier "F"			
1-3-3	0.0100	13.6	1,360
1-10-3	0.0105	12.6	1,200
2-3-3	0.0109	13.8	1,270
		AVERAGE:	1,280

DIELECTRIC STRENGTH (continued)

CONDITIONING: Tested at room temperature after conditioning five minutes at 450°F.

SPECIMEN	THICKNESS INCHES	BREAKDOWN VOLTAGE KV	DIELECTRIC STRENGTH VOLTS/MIL
Supplier "A"			
1-3-5	0.0100	13.9	1,390
1-10-5	0.0100	13.7	1,370
2-3-5	0.0103	13.3	1,290
		AVERAGE:	1,350
Supplier "F"			
1-3-5	0.0112	14.3	1,280
1-10-5	0.0107	13.7	1,280
2-3-5	0.0107	13.1	1,220
		AVERAGE:	1,260

CONDITIONING: Tested at room temperature after conditioning four hours at 350°F.

SPECIMEN	THICKNESS INCHES	BREAKDOWN VOLTAGE KV	DIELECTRIC STRENGTH VOLTS/MIL
Supplier "A"			
1-3-2	0.0097	13.6	1,400
1-10-2	0.0095	13.9	1,460
2-3-2	0.0095	13.6	1,430
		AVERAGE:	1,430
Supplier "F"			
1-3-2	0.0105	13.9	1,320
1-10-2	0.0105	13.9	1,320
2-3-2	0.0109	14.3	1,310
		AVERAGE:	1,320

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DIELECTRIC STRENGTH (continued)

CONDITIONING: Tested at room temperature after conditioning four hours at 400°F.

SPECIMEN	THICKNESS INCHES	BREAKDOWN VOLTAGE KV	DIELECTRIC STRENGTH VOLTS/MIL
Supplier "A"			
1-3-4	0.0093	13.6	1,460
1-10-4	0.0097	13.3	1,370
2-3-4	0.0096	13.6	1,420
		AVERAGE:	1,420
Supplier "F"			
1-3-4	0.0105	13.9	1,320
1-10-4	0.0107	13.9	1,300
2-3-4	0.0106	13.9	1,310
		AVERAGE:	1,310

CONDITIONING: Tested at room temperature after conditioning four hours at 450°F.

SPECIMEN	THICKNESS INCHES	BREAKDOWN VOLTAGE KV	DIELECTRIC STRENGTH VOLTS/MIL
Supplier "A"			
1-3-6	0.0099	14.6	1,470
1-10-6	0.0091	12.3	1,350
2-3-6	0.0098	13.6	1,390
		AVERAGE:	1,400
Supplier "F"			
1-3-6	0.0106	14.6	1,380
1-10-6	0.0108	14.6	1,350
2-3-6	0.0104	13.9	1,340
		AVERAGE:	1,360

DELSEN TESTING LABCRATORIES, INC.
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FLEXURAL STRENGTH AND MODULUS
Test Rate: 0.04 Inch/Minute
Span: 1.500 Inches

Mfg. Tech. M-24-6-713, Item #17
TEST METHOD: ASTM D-790 or FTMS 406, Method 1031

TEMP. °F	SPECIMEN	THICKNESS INCHES	WIDTH INCHES	MAXIMUM LOAD POUNDS	TYPE OF FAILURE	FLEXURAL STRENGTH PSI	FLEXURAL MODULUS PSI x 10^6
Supplier "A"							
-80	1	0.0964	0.947	314	T	80,300	3.8
-70	2	0.0934	0.947	294	T	80,100	3.9
-60	3	0.0956	0.947	295	T	76,700	3.8
-50	4	0.0949	0.948	298	T	78,500	3.8
-40	5	0.0928	0.947	295	T	81,400	3.9
-30	6	0.0959	0.947	299	T	77,200	3.7
-20	7	0.0933	0.947	289	T	78,900	3.8
-10	8	0.0956	0.947	276	T	71,800	3.6
0	9	0.0965	0.946	272	T	69,500	3.6
+10	10	0.0929	0.946	274	T	75,500	3.8
+20	11	0.0950	0.948	261	T	68,600	3.8
+30	12	0.0946	0.947	265	T	70,400	3.7
+40	13	0.0947	0.947	260	T	68,900	3.7
+50	14	0.0954	0.947	253	T	66,000	3.7
+60	15	0.0960	0.945	240	T	62,000	3.6
Supplier "F"							
-80	1	0.0815	0.945	208.0	T	74,600	3.0
-70	2	0.0728	0.946	173.4	T	77,800	3.1
-60	3	0.0738	0.947	176.4	T	77,000	3.1
-50	4	0.0750	0.946	180.4	T	76,300	3.0
-40	5	0.0783	0.947	187.6	T	72,700	2.9
-30	6	0.0821	0.946	187.6	T	66,200	2.8
-20	7	0.0846	0.947	190.0	T	63,100	2.7
-10	8	0.0825	0.947	179.6	T	62,700	2.8
0	9	0.0780	0.946	164.4	T	64,300	2.7
+10	10	0.0852	0.947	181.0	T	59,200	2.6
+20	11	0.0734	0.947	155.0	T	68,400	3.0
+30	12	0.0769	0.947	153.3	T	61,600	2.7
+40	13	0.0788	0.946	162.9	T	62,400	2.7
+50	14	0.0704	0.947	138.3	T	66,300	2.9
+60	15	0.0772	0.893	147.3	T	62,300	2.8

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FLEXURAL MODULUS
Test Rate: 0.04 Inch/Minute
Span: 1.500 Inches

TEST METHOD: ASTM D-790

TEMPERATURE °F	THICKNESS INCHES	WIDTH INCHES	MAXIMUM LOAD POUNDS	FLEXURAL MODULUS PSI x 10^6
Supplier "F"				
0				
-80	0.0761	0.793	70 Max	3.4
-70	0.0761	0.793	70 Max	3.2
-60	0.0761	0.793	70 Max	3.2
-50	0.0761	0.793	70 Max	3.2
-40	0.0761	0.793	70 Max	3.2
-30	0.0761	0.793	70 Max	3.2
-20	0.0761	0.793	70 Max	3.2
-10	0.0761	0.793	70 Max	3.1
0	0.0761	0.793	70 Max	3.0
+10	0.0761	0.793	70 Max	3.0
+20	0.0761	0.793	70 Max	3.0
+30	0.0761	0.793	70 Max	3.0
+40	0.0761	0.793	70 Max	3.0
+50	0.0761	0.793	70 Max	3.0
+60	0.0761	0.793	70 Max	2.9
Supplier "A"				
0				
-80	0.0955	0.946	100 Max	3.8
-70	0.0955	0.946	100 Max	3.7
-60	0.0955	0.946	100 Max	3.7
-50	0.0955	0.946	100 Max	3.7
-40	0.0955	0.946	100 Max	3.6
-30	0.0955	0.946	100 Max	3.7
-20	0.0955	0.946	100 Max	3.8
-10	0.0955	0.946	100 Max	3.6
0	0.0955	0.946	100 Max	3.6
+10	0.0955	0.946	100 Max	3.6
+20	0.0955	0.946	100 Max	3.7
+30	0.0955	0.946	100 Max	3.7
+40	0.0955	0.946	100 Max	3.7
+50	0.0955	0.946	100 Max	3.6
+60	0.0955	0.946	100 Max	3.6

REPORT

TRUESDAIL LABORATORIES, INC.

CHEMISTS - MICROBIOLOGISTS - ENGINEERS

RESEARCH — DEVELOPMENT — TESTING

4101 N. FIGUEROA STREET
LOS ANGELES 90065
AREA CODE 213 • 225-1564
CABLE: TRUELABS

CLIENT: Delsen Testing Laboratories, Inc.
1031 Flower Street
Glendale, Ca. 91201
Attention: Mr. Gerald Cave

DATE May 8, 1978

RECEIVED March 20, 1978

LABORATORY NO. 20203-1

SAMPLE Eight samples of material

P. O. No. 2804 Job No. T.15159

INVESTIGATION Fungus Resistance Testing (ASTM G-21-70)

RESULTS

Ten day old cultures of the following pure culture funci were harvested, washed and their spore counts adjusted to 1,000,000 (+200,000) per ml.

Organisms	ATCC Number
Aspergillus niger	9642
Penicillium funiculosum	9644
Chaetomium globosum	6205
Trichoderma sp	9645
Pullularia pullulans	9348

The spore suspensions were combined and sprayed onto the samples and controls which were placed on sterile nutrient salts agar. The samples were incubated at 30°C for 28 days and examined weekly. The results of the examination are given below:

	Sample Designation	Observations (Rating)* 7 days	14 days	21 days	28 days
Supplier "F"	1. 1, 2, 3, 4	0	0	0	0
Supplier "A"	2. 1, 2, 3, 4	0	0	0	0
	3. Controls (4 filter paper)	3	4	4	4

*Rating: 0, no growth; 1, traces of growth; 2, light growth; 3, medium growth; 4, heavy growth

TRUESDAIL LABORATORIES, INC.

Page 2
Lab No. 20203-1

Conclusion

The samples submitted were found to have sufficient fungus resistance when tested in accordance with ASTM G-21.

Respectfully submitted,

TRUESDAIL LABORATORIES, INC.

Karl W. Schiller

Karl W. Schiller, M.S.
Chief Microbiologist

DELSEN TESTING LABORATORIES, INC.
1031 FLOWER STREET • GLENDALE, CALIFORNIA 91201
(213) 247-4106
(213) 245-8517

DISCLAIMER

As a mutual protection to clients, the public and Delsen Testing Laboratories, Inc., this report is submitted for the exclusive use of the client to whom it is addressed. This report applies only to the sample (s) tested and is not necessarily indicative of the qualities of apparently similar or identical products. Use of this report, whether in whole or in part, or of any seals or insignia connected therewith, in any advertising or publicity matter, without prior written authorization from Delsen Testing Laobratories, Inc. is prohibited.

Respectfully submitted,

DELSEN TESTING LABORATORIES, INC.

DELSEN TESTING LABORATORIES, INC.
1031 FLOWER STREET • GLENDALE, CALIFORNIA 91201
(213) 247-4106
(213) 245-8517

TEST REPORT

In Account with GENERAL DYNAMICS P.O. Box 2507 Pomona, CA. 91766	Date 5/24/78	Page 1 of 1 Pages
	W.O. No T 15159	P O No P0083165
	Identification As noted	Shipper No number

SPECIFICATION: MIL-P-55617A

VOLUME AND SURFACE RESISTIVITY

SPECIMEN	CONDITION	THICKNESS INCHES	SURFACE RESISTIVITY MEGOHMS	VOLUME RESISTIVITY MEGOHM-CM
1 Supplier "F"	1	0.0121	1.6×10^6	9.8×10^8
2	1	0.0120	4.8×10^7	4.2×10^8
3	1	0.0104	3.8×10^8	2.5×10^8
4	1	0.0105	4.5×10^6	4.1×10^8
1 Supplier "A"	1	0.0091	2.8×10^8	1.3×10^8
2	1	0.0094	2.3×10^8	1.3×10^8
3	1	0.0104	5.4×10^7	6.5×10^7
4	1	0.0100	1.5×10^6	8.5×10^7
1 Supplier "F"	2	0.0121	6.4×10^6	4.2×10^7
2	2	0.0120	4.8×10^6	2.7×10^7
3	2	0.0104	5.7×10^6	3.5×10^7
4	2	0.0105	5.4×10^6	3.5×10^7
1 Supplier "A"	2	0.0091	1.6×10^5	3.8×10^7
2	2	0.0094	4.5×10^5	3.7×10^7
3	2	0.0104	2.2×10^5	4.1×10^7
4	2	0.0100	8.6×10^4	5.1×10^7
		MINIMUM REQUIREMENT:	6.0×10^4	6.0×10^4

1=Tested at 35°C and 90% Relative Humidity after conditioning C-96/35/90

2=Tested at 200°C after conditioning E-24/200.

Respectfully submitted,

Gerard Blane

DELSEN TESTING LABORATORIES, INC.

RESEARCH AND DEVELOPMENT TESTING

DELSEN FORM 102

DATA SHEETS OF TESTS
PERFORMED BY TRUESDAIL LABORATORIES

REPORT

TRUESDAIL LABORATORIES, INC.

CHEMISTS - MICROBIOLOGISTS - ENGINEERS

RESEARCH — DEVELOPMENT — TESTING

4101 N. FIGUEROA STREET
LOS ANGELES 90065
AREA CODE 213 • 225-1564
CABLE: TRUELABS

CLIENT General Dynamica Corporation
Pomona Division
P. C. Box 2507
Pomona, California 91766
Attention: Mr. Joe Reavill M2/4-26

SAMPLE Three (3) plastic sheets as shown
P. O. NO. 107535

DATE May 24, 1978

RECEIVED May 12, 1978

LABORATORY NO. 21226

INVESTIGATION Taber Abrasion Resistance

RESULTS

The samples were tested using CS 17 wheels with a 1000 gram load.

Sample	Weight Loss, Milligrams
Polyimide, light color	13.7
Polyimide, dark color	10.6
Epoxy	18.0

The abraded samples are enclosed for your examination.

Respectfully submitted,

TRUESDAIL LABORATORIES, INC.

K.A. Smitheman

Kent A. Smitheman
Chief Chemist

DATA SHEETS OF TESTS
PERFORMED BY GENERAL DYNAMICS POMONA

NUMBER 12

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 3/24/79

TYPE OF TEST SURFACE FINISH

EQUIPMENT REQUIRED BENDIX PROFILOMETER WITH .030 CUT-OFF CAPABILITY MODEL 5 TYPE QB TRACING HEAD LC 1-63 PILOTOR TYPE VE

SPECIFICATION MIL-P-55617 B

UNITS OF RECORDED VALUES μ INCHES

MIN/MAX VALUE MAX 20 μ INCH

TEST PERFORMED BY E. McGUIRE

MATERIAL DESCRIPTION AND SUPPLIER .010" THICK POLYIMIDE GLASS/ 1 OZ COPPER CLAD ONE SIDE

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES LONGITUDINAL	RECORDED VALUES TRANSVERSE	CALC. AVG.		SUPPLIER RANKING
1	A	5μ, 8μ, 5μ	9μ, 8μ, 8μ	7μ inches		1
2	A	6, 3, 5	5, 8, 9	6μ inches		
3	A	6, 6, 5	8, 9, 9	7μ inches		
4	F	10, 11, 10	14, 12, 14	12μ inches		2
5	F	9, 7, 7	13, 13, 13	10μ inches		
6	F	9, 11, 8	11, 11, 12	10μ inches		
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

OBSERVATIONS

NUMBER 13

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 3/27/78

TYPE OF TEST DIMENSIONAL - THICKNESS

EQUIPMENT REQUIRED 1" STARRETT VERNIER MICROMETER

SPECIFICATION MIL-P-55617B CLASS I

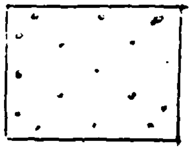
MIN/MAX VALUE TOLERANCE IS ± .002 NOMINAL - .0114

UNITS OF RECORDED VALUES INCHES

TEST PERFORMED BY J A REAVILL & M. BEAM

MATERIAL DESCRIPTION .010" POLYIMIDE GLASS/ 1 OZ COPPER CLAD ONE SIDE

AND SUPPLIER



SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1	A	.0117, .0099, .0119, .0104			
2		.0099, .0118, .0106, .0104	.0108		PASS
3		.0107, .0114, .0105, .0112			
4					
5	F	.0118, .0112, .0123, .0123			
6		.0110, .0114, .0122, .0121	.0118		PASS
7		.0120, .0118, .0118, .0115			
8		.0117			
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

OBSERVATIONS VALUES TAKEN IN AREAS SHOWN ABOVE AND IN EXHIBIT I

NUMBER 14

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 7/27/78

TYPE OF TEST WARPAGE

EQUIPMENT REQUIRED SURFACE PLATE AND 6" SCALE

SPECIFICATION MIL-P-55617

MIN/MAX VALUE

UNITS OF RECORDED VALUES INCHES

TEST PERFORMED BY J A REAVILL

MATERIAL DESCRIPTION AND SUPPLIER .010 POLYIMIDE GLASS / 1 OZ COPPER CLAD ONE SIDE

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1	A	.58"			2
2	F	0.15"			1
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

OBSERVATIONS ALL VALUES MEASURED ON MATERIAL AS RECEIVED — SHEET SIZE 12" X 12"

NUMBER 15

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 3-28-78

TYPE OF TEST DIMENSIONAL STABILITY

EQUIPMENT REQUIRED BORROW DALE OPTI-PLOT WITH CIRCON MICRO TECH VIDEO SYSTEM 50X TV SCREEN AND HEIDENHAIN DIGITAL READ-OUT AND EXCELLON DIGITAL DRILLING MACHINE

SPECIFICATION MIL-P-55617

UNITS OF RECORDED VALUES INCHES

MIN/MAX VALUE MAX DISPLACEMENT ± .0003 INCHES/INCH

TEST PERFORMED BY J. A. RENVILL - J. DENAULT

MATERIAL DESCRIPTION .010 POLYIMIDE GLASS LAMINATE SINGLE CLAD

AND SUPPLIER "A"

SAMPLE #	SUPPLIER CODE LETTER CONDITIONING	RECORDED VALUES MACHINE	WARP	Δ MACHINE	Δ WARP	PASS-FAIL
1 - 14A	UN-ETCHED	10.0017	10.0020			
2	ETCHED	10.0028	10.0048	+ .00[illegible]	+.0028	PASS
3	AFTER ELEV. TEMP.	10.0076	10.0062	+.0059	+.0042	FAIL
4	AFTER THERM CYCLE	10.0079	10.0047	+.0062	+.0027	FAIL
5 14-B	UN ETCHED	10.00195	10.0037			
6	ETCHED	10.0010	10.0036	+.0009	+.0001	PASS
7	AFTER ELEV TEMP	10.0066	[illegible]	+.0047	+.0020	FAIL
8	AFTER THERM CYCLE	10.0070	10.0068	+.0050	+.0031	FAIL
9 14-C	UN-ETCHED	10.0021	10.0024			
10	ETCHED	10.0042	10.0048	+.0021	+.0024	PASS
11	AFTER ELEV TEMP	10.0053	10.0056	+.0032	+.0032	FAIL
12	AFTER THERM CYCLE	10.0063	10.0069	+.0042	+.0045	FAIL
13						
14						
15						
16						
17						
18						
19						
20						

OBSERVATIONS NOTE: ALL VALUES FOR Δ MUST BE DIVIDED BY 10 TO DETERMINE INCHES/INCH

NUMBER 16

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 3-28-78

TYPE OF TEST DIMENSIONAL STABILITY

EQUIPMENT REQUIRED BOrROW DALE OPTI-PLOT WITH CIRCON MICRO TECH VIDEO SYSTEM 50X TV SCREEN AND CROSSHAIR DIGITAL READ-OUT AND EXCELLON DIGITAL DRILLING MACHINE

SPECIFICATION MIL-P-55617

UNITS OF RECORDED VALUES INCHES

MIN/MAX VALUE MAX DISPLACEMENT ± .0003 INCHES/INCH

TEST PERFORMED BY J. A. REALLL - J. DEVAULT

MATERIAL DESCRIPTION AND SUPPLIER .010 POLYIMIDE GLASS LAMINATE " " SINGLE CLAD " F "

SAMPLE #	SUPPLIER CODE LETTER CONDITIONING	RECORDED VALUES MACHINE	WARP	Δ MACHINE	Δ WARP	PASS-FAIL
1 - 14A	UN-ETCHED	10.0026	10.0002			
2	ETCHED	10.0022	9.9999	-.0004	-.0003	PASS
3	AFTER ELEV TEMP	10.0044	9.9990	+.0018	-.0012	PASS
4	AFTER THERM CYCLE	10.0034	10.0003	+.0008	-.0001	PASS
5 / 14-B	UN-ETCHED	10.0022	9.9994	+.0007	.0000	PASS
6	ETCHED	10.0031	9.9994	+.0027	-.0002	PASS
7	AFTER ELEV TEMP	10.0049	9.9992	+.0024	+.0016	PASS
8	AFTER THERM CYCLE	10.0046	10.0010			
9 / 14-C	UN-ETCHED	10.0016	9.9974			
10	ETCHED	10.0027	9.9993	+.0011	+.0017	PASS
11	AFTER ELEV TEMP	10.0028	9.9984	+.0012	+.0010	PASS
12	AFTER THERM CYCLE	10.0024	9.9993	+.0008	+.0019	PASS
13						
14						
15						
16						
17						
18						
19						
20						

OBSERVATIONS NOTE: ALL VALUES FOR Δ MUST BE DIVIDED BY 10 TO DETERMINE IN./IN.

NUMBER 17

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 7/24/78

TYPE OF TEST SOLDER DIP UNFLUXED & FLUXED

EQUIPMENT REQUIRED SOLDER POT

SPECIFICATION MIL-P-55617B

UNITS OF RECORDED VALUES 500 °F

MIN/MAX VALUE

TEST PERFORMED BY M. BEAM

MATERIAL DESCRIPTION AND SUPPLIER .010 POLYIMIDE CLASS 1 OZ CU ONE SIDE " " " " "A" & "F"

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES FLUXED	RECORDED VALUES UNFLUXED	CALC. AVG.		SUPPLIER RANKING
1	A	NO DEGRADATION	NO DEGRADATION			
2	|	|	|			
3	|	|	|			
4	|	|	|			
5	|	|	|			
6	|	|	|			
7	|	|	|			
8	|	|	|			
9		|	|			
10	F	NO DEGRADATION	NO DEGRADATION			
11	|	|	|			
12	|	|	|			
13	|	|	|			
14	|	|	|			
15	|	|	|			
16	|	|	|			
17	|	|	|			
18	|	|	|			
19						
20						

OBSERVATIONS NOTE IMMERSION TIME WAS 20 SECONDS

NUMBER 19

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 4-5-78

TYPE OF TEST PEEL TEST, COPPER FOIL AS ETCHED

EQUIPMENT REQUIRED INSTRON TENSILE TESTING MACHINE

SPECIFICATION MIL-P-55617

MIN/MAX VALUE MIN 5.0 lbs/in

UNITS OF RECORDED VALUES lbs

USING A PULL RATE OF 2" PER MINUTE

TEST PERFORMED BY F. SAWYER

MATERIAL DESCRIPTION .010 POLYIMIDE GLASS LAMINATE SINGLE CLAD 1 OZ COPPER

AND SUPPLIER

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1 - 11A	A	5.5			
2		5.7			
3		5.6			
4		4.7			
5		5.8	5.5 lb		PASS
6		4.7			
7		6.0			
8		5.7			
9		6.0			
10 - 11A		5.4			
11		5.4			
12		5.0			
13		4.5	5.3 lb		PASS
14		5.6			
15		5.3			
16		5.5			
17		5.4			
18					
19					
20					

160

OBSERVATIONS NOTE: ALL TEST STRIPS WERE [illegible] ... ACTUAL LINE MEASUREMENTS [illegible] .24 WIDTHS

NUMBER 19

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 4-5-78

TYPE OF TEST PEEL TEST COPPER FOIL AFTER SOLDER DIP

EQUIPMENT REQUIRED INSTRON TENSILE TESTING MACHINE USING A PULL RATE OF 2" PER MINUTE

SPECIFICATION MIL-P-55617

UNITS OF RECORDED VALUES lbs

MIN/MAX VALUE MIN 5.0 lb/IN

TEST PERFORMED BY E. SAWYER

MATERIAL DESCRIPTION AND SUPPLIER .010 POLYIMIDE GLASS LAMINATE SINGLE CLAD / 1OZ COPPER

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1 - 11A	"A"	6.2			
2		6.0			
3		4.6			
4		6.1			
5 - 11B		6.1			
6		6.2	5.7 lb		
7		5.8			
8 - 11C		4.6			
9		5.0			
10		6.2			
11 - 11A	"F"	3.6			
12		3.5			
13		3.8			
14 - 11B		4.3	4.4 lb		
15		4.8			
16		4.7			
17 - 11C		4.8			
18		4.9			
19		5.0			
20					

OBSERVATIONS NOTE: ALL TEST STRIPS WERE 1/8" WIDE ETCHED LINES. ACTUAL LINE MEASUREMENTS WERE .124 WIDE

NUMBER 20

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 4-5-78

TYPE OF TEST PEEL TEST COPPER FOIL AFTER ELEVATED TEMP EQUIPMENT REQUIRED INSTRON TENSILE TESTING MACHINE

SPECIFICATION MIL-P-55617

UNITS OF RECORDED VALUES lbs USING 2" PER MIN PULL

MIN/MAX VALUE MIN 5.0 lbs/in

TEST PERFORMED BY [illegible] SAWYER

MATERIAL DESCRIPTION AND SUPPLIER CLC POLYIMIDE GLASS LAMINATE RATE SINGLE CLAD / 1 OZ CU

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1 - 11A	"A"	5.7			
2		4.6			
3		5.5			
4 - 1B		6.2			
5		6.0	5.4		
6		5.8			
7 - 1C		5.7			
8		5.6			
9		3.7			
10 - 11A	"F"	4.2			
11		5.4			
12		5.4			
13 - 11B		5.3			
14		4.0	4.9		
15		4.5			
16		5.3			
17 - 11C		[illegible]			
18		4.9			
19		5.2			
20					

OBSERVATIONS NOTE: ALL TEST STRIPS WERE 1/8" WIDE ETCHED LINES, ACTUAL LINE MEASUREMENTS WERE .124

NUMBER 21

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 4-5-78

TYPE OF TEST PEEL TEST COPPER FOIL AFTER TEMP CYCLE

EQUIPMENT REQUIRED INSTRON TENSILE TESTING MACHINE USING A PULL RATE OF 2" PER MIN

SPECIFICATION MIL-P-55617

UNITS OF RECORDED VALUES lbs

MIN/MAX VALUE MIN 5.0 lb/in

TEST PERFORMED BY F. SAWYER

MATERIAL DESCRIPTION AND SUPPLIER .062 POLYIMIDE GLASS LAMINATE SINGLE CLAD/1OZ COPPER

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1 - 11A	"A"	4.2			
2		5.5			
3		5.0			
4 - 11B		6.7			
5		6.6			
6		6.6	5.8 lb		
7 - 11C		6.5			
8		6.7			
9		5.1			
10 - 11A	"F"	5.7			
11 ~~11B~~		4.6			
12		5.5			
13 11B		4.8	5.1 lb		
14		5.2			
15		4.7			
16 - 11C		5.3			
17		5.3			
18					
19					
20					

OBSERVATIONS NOTE: ALL TEST STRIPS WERE 1/8" WIDE ETCHED LINES. ACTUAL LINE MEASUREMENTS WERE .124"

NUMBER 22

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 4-5-78

TYPE OF TEST PEEL TEST COPPER FOIL AFTER EXPOSURE TO PLATING SOL

EQUIPMENT REQUIRED INSTRON TENSILE TESTING MACHINE USING A 2" PER MINUTE PULL RATE

SPECIFICATION

MIN/MAX VALUE MIN 5.0 lbs/inch

UNITS OF RECORDED VALUES lb

TEST PERFORMED BY F SAUVER

MATERIAL DESCRIPTION AND SUPPLIER .010 POLYIMIDE GLASS LAMINATE SINGLE CLAD / 1 oz COPPER

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1 - 11A	"A"	6.0			
2		5.5			
3		5.8			
4 - 11B		5.4			
5		5.8	5.9		
6		5.8			
7 - 11C		6.0			
8		6.4			
9		5.8			
10 - 11A	"F"	4.6			
11		5.0			
12		4.8			
13 - 11B		4.8	4.6		
14		4.8			
15		4.4			
16 - 11C		4.4			
17		4.4			
18		4.6			
19					
20					

OBSERVATIONS NOTE ALL TEST STRIPS WERE 1/8" WIDE ETCHED LINES, ACTUAL LINE MEASUREMENTS WERE .124

NUMBER 23

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 5-9-78

TYPE OF TEST TENSILE STRENGTH

EQUIPMENT REQUIRED INSTRON TENSILE TESTING MACHINE

SPECIFICATION ASTM-D-638

UNITS OF RECORDED VALUES lb/in²

MIN/MAX VALUE 40×10^3 PSI. MIN

TEST PERFORMED BY R. BARKER

MATERIAL DESCRIPTION .010 POLYIMIDE GLASS LAMINATE DOUBLE CLAD/COPPER REMOVED

AND SUPPLIER "A" AND "F"

SAMPLE #	SUPPLIER CODE LETTER	~~RECORDED~~ CALCULATED VALUES	CALC. AVG.		SUPPLIER RANKING
1	A	31,500 PSI			
2	|	29,703 PSI	29669 PSI		
3	|	27,804 PSI			
4	F	28,802 PSI			
5	|	28,520 PSI	28081 PSI		
6	|	26,920 PSI			
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

OBSERVATIONS

NUMBER ________

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE ________

TYPE OF TEST ________ EQUIPMENT REQUIRED ________

SPECIFICATION ________ UNITS OF RECORDED VALUES ________

MIN/MAX VALUE ________

TEST PERFORMED BY ________

MATERIAL DESCRIPTION AND SUPPLIER ________

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES		CALC. AVG.		SUPPLIER RANKING
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

OBSERVATIONS

NUMBER 25

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 5/25/78

TYPE OF TEST DIMENSIONAL STABILITY

EQUIPMENT REQUIRED BORROW DALE OPTI-PLOT WITH CIRCON MICRO TECH VIDEO SYSTEM 50X TV SCREEN AND HEIDENHAIN DIGITAL READ-OUT AND EXCELLON DIGITAL DRILLING MACHINE

SPECIFICATION MIL-P-55617B

MIN/MAX VALUE MAX DISPLACEMENT ±.0003"/IN EXCEPT AFTER TEMP CYCLE .0005"/IN

UNITS OF RECORDED VALUES INCHES

TEST PERFORMED BY J. A. REAVILL & G. CLARK

MATERIAL DESCRIPTION .010 POLYIMIDE GLASS LAMINATE DOUBLE CLAD

AND SUPPLIER "F"

SAMPLE #	SUPPLIER CODE LETTER CONDITIONING	RECORDED VALUES MACHINE	FILL	CALC. AVG. Δ MACHINE	Δ FILL	SUPPLIER RANKING
1-MIDDLE	UN-ETCHED	10.0007	9.9999			
2	AFTER ETCHING	9.9978	9.9968	.0029	.0031	
3	AFTER ELEV. TEMP	9.9959	9.9968	.0048	.0031	
4	AFTER TEMP CYCLE	9.9961	9.9972	.0046	.0027	
5-EDGE-1	UN-ETCHED	10.0008	9.9997			
6	AFTER ETCHING	9.9981	9.9967	.0027	.0030	
7	AFTER ELEV. TEMP	9.9973	9.9963	.0035	.0034	
8	AFTER TEMP CYCLE	9.9976	9.9970	.0032	.0037	
9 EDGE-2	UN-ETCHED	10.0004	9.9999			
10	AFTER ETCHING	9.9987	9.9969	.0017	.0030	
11	AFTER ELEV. TEMP	10.0005	9.9992	.0001	.0007	
12	AFTER TEMP CYCLE	10.0009	9.9999	.0005	.0010	
13						
14						
15						
16						
17						
18						
19						
20						

OBSERVATIONS

NUMBER [illegible]

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE [illegible]

TYPE OF TEST [illegible] EQUIPMENT REQUIRED [illegible]

SPECIFICATION [illegible]

UNITS OF RECORDED VALUES [illegible]

MIN/MAX VALUE [illegible]

TEST PERFORMED BY [illegible]

MATERIAL DESCRIPTION [illegible]

AND SUPPLIER [illegible]

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1	[illegible]	[illegible]			
2		[illegible]			
3		[illegible]	[illegible]		
4		[illegible]			
5		[illegible]			
6	[illegible]	[illegible]			
7		[illegible]			
8		[illegible]			
9		[illegible]			
10		[illegible]	[illegible]		
11		[illegible]			
12		[illegible]			
13		[illegible]			
14		[illegible]			
15					
16					
17					
18					
19					
20					

OBSERVATIONS

NUMBER 27

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 5/29/78

TYPE OF TEST WATER ABSORPTION

EQUIPMENT REQUIRED

SPECIFICATION ASTM - D - 570

UNITS OF RECORDED VALUES Gms

MIN/MAX VALUE MAX 3%

TEST PERFORMED BY R. BAAKER

MATERIAL DESCRIPTION .062 THICK POLYIMIDE GLASS LAMINATE UNCLAD

AND SUPPLIER "A" AND "F"

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
		WT GAIN			
1	"A"	6.0775 - 6.0944 — .278%			
2		6.1045 - 6.1145 — .163%	.22%		
3					
4	"F"	4.2729 - 4.2838 - .25%			
5		4.6975 - 4.7087 - .24%	.25%		
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

OBSERVATIONS

NUMBER 29

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 5/30/78

TYPE OF TEST [illegible] TEST AS ETCHED

EQUIPMENT REQUIRED INSTRON TENSILE TESTING MACHINE

SPECIFICATION [illegible] 55617B AS ETCHED

MIN/MAX VALUE 5.0 lb [illegible] AVG

UNITS OF RECORDED VALUES lb

TEST PERFORMED BY [illegible]

MATERIAL DESCRIPTION [illegible] DOUBLE CLAD

AND SUPPLIER A [illegible]

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1	F	[illegible] SAMPLE [illegible]	[illegible]		
2		[illegible] SAMPLE TORE	[illegible]		
3		[illegible]	[illegible]		
4		[illegible] SAMPLE TORE	[illegible]		
5	A	[illegible]	[illegible]		
6		[illegible]	[illegible]		
7		[illegible]	[illegible]		
8		[illegible]	[illegible]		
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

OBSERVATIONS

NUMBER 27

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 5 [illegible]/78

TYPE OF TEST PEEL TESTS - AFTER SOLDER DIP

EQUIPMENT REQUIRED INSTRON TENSILE TESTING MACHINE

SPECIFICATION MIL-P-55617B

MIN/MAX VALUE MIN 5.0 lb

UNITS OF RECORDED VALUES lb

TEST PERFORMED BY R [illegible]ARKER

MATERIAL DESCRIPTION [illegible] POLYIMIDE GLASS LAMINATE DOUBLE CLAD

AND SUPPLIER A [illegible] F

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1	A 11_2	8.6, 8.6, 8.8, 8.8	8.7		
2	11_2	7.4, 7.4, 7.4, 7.4	7.4		
3	$\perp_1$	8.3, 8.5, 8.3, 8.3	8.3		
4	$\perp_2$	7.2, 7.0, 7.2, 7.0	7.1		
5	F 11_1	11.5, 10.9, 11.0, 10.4	10.8		
6	11_2	10.6, 11.2, 11.5, [illegible]2	11.1		
7	$\perp_1$	[illegible]	[illegible].3		
8	$\perp_2$	[illegible]	11.8		
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

OBSERVATIONS

NUMBER [illegible]

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE [illegible]

TYPE OF TEST [illegible] AFTER ELEVATED [illegible]

EQUIPMENT REQUIRED [illegible] TESTING MACHINE

SPECIFICATION [illegible]

UNITS OF RECORDED VALUES [illegible]

MIN/MAX VALUE [illegible]

TEST PERFORMED BY [illegible]

MATERIAL DESCRIPTION [illegible]

AND SUPPLIER [illegible]

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1	A [illegible]	[illegible]	[illegible]		
2	[illegible]	[illegible]	[illegible]		
3	[illegible]	[illegible]	[illegible]		
4	[illegible]	[illegible]	[illegible]		
5	[illegible]	[illegible]	[illegible]		
6	[illegible]	[illegible]	[illegible]		
7	[illegible]	[illegible]	[illegible]		
8	[illegible]	[illegible]	[illegible]		
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

OBSERVATIONS

NUMBER 31

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 5/30/78

TYPE OF TEST PEEL TEST - AFTER THERMAL CYCLE

EQUIPMENT REQUIRED INSTRON TENSILE TESTING MACHINE

SPECIFICATION MIL-P-55617B

MIN/MAX VALUE 5.0 MIN

UNITS OF RECORDED VALUES

TEST PERFORMED BY R. BARKER

MATERIAL DESCRIPTION .010 POLYIMIDE GLASS LAMINATE DOUBLE CLAD

AND SUPPLIER A AND F

SAMPLE #	SUPPLIER CODE LETTER		RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1	F	∥1	10.6, 10.9, 10.8, 10.6	10.7		
2		∥2	11.0, 10.9, 10.8, 10.5	10.8		
3		⊥1	10.4, 11.3, 11.0 (1 more)	10.9		
4		⊥2	10.9, 10.8, 10.6, 11.0	10.8		
5	A	∥1	8.5, 8.5, 8.6, 8.2	8.5		
6		∥2	7.0, 7.5, 8.6, 7.8	7.7		
7		⊥1	8.5, 9.0, 7.5, 8.0	8.4		
8		⊥2	9.0, 9.0, 8.5, 7.0	8.3		
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

OBSERVATIONS

NUMBER [illegible]

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 5/30/78

TYPE OF TEST Peel tests - after exposure to [illegible] solution

EQUIPMENT REQUIRED [illegible] testing machine

SPECIFICATION [illegible] 55617 R

MIN/MAX VALUE [illegible] 5.0 lb

UNITS OF RECORDED VALUES lbs

TEST PERFORMED BY [illegible] Barker

MATERIAL DESCRIPTION [illegible] glass laminate [illegible]

AND SUPPLIER A and [illegible]

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1	F [illegible]	11.4 12.0 11.4 [illegible]	[illegible]		
2	[illegible]	[illegible] 11.5 [illegible]	11.1		
3	[illegible]	[illegible]	[illegible]		
4	[illegible]	[illegible] 11.2 11.5	[illegible]		
5	A [illegible]	8.5 [illegible] 7.7	8.1		
6	[illegible]	[illegible]	[illegible]		
7	[illegible]	[illegible]	[illegible]		
8	[illegible]	[illegible]	[illegible]		
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

OBSERVATIONS

NUMBER 33

MATERIAL TEST REPORT

For Navy Contract # N00123-77-C-1192

DATE 6/2/78

TYPE OF TEST FOIL THICKNESS

EQUIPMENT REQUIRED

SPECIFICATION MIL - F - 55561

MIN/MAX VALUE

UNITS OF RECORDED VALUES

TEST PERFORMED BY J A REAVILL

MATERIAL DESCRIPTION C/C POLYIMIDE GLASS LAMINATE
" " CLAD TWO SIDES

AND SUPPLIER "A" AND "F"

SAMPLE #	SUPPLIER CODE LETTER	RECORDED VALUES	CALC. AVG.		SUPPLIER RANKING
1	"A"	.00123			
2	|	.00127	.00112		
3	|	.00126			
4	"F"	.00113			
5	|	.00123	.00125		
6	|	.0010			
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

* [illegible]VATIONS

Peabody Testing
MAGNAFLUX

6800 E. WASHINGTON BOULEVARD, LOS ANGELES, CALIFORNIA 90040
AREA CODE (213) 685-6001 , 724-3811

LABORATORY NO	95188-4-1 & -2
DATE REPORTED	4-6-78
PURCHASE ORDER NO	H23568-PB
SHIPPER NO	NA61926-P
SAMPLE SUBMITTED	Copper
MATERIAL SPECIFICATION	
TEST METHOD	ASTM E53

General Dynamics
P O Box 2507
Pomona, CA 91766
Attn: Wayne Gross

QUANTITATIVE CHEMICAL ANALYSES

Copper on glass/polyimide circuit board material

	SAMPLE	% Cu
-1	A-6-B	99.87
-2	F-6-B	99.71

BY: A.W. Forbes
PEABODY TESTING MAGNAFLUX

DATA SHEETS OF TESTS
PERFORMED BY PEABODY TESTING (MAGNAFLUX)

EXHIBIT 24
COMPILATION OF TEST RESULTS
FOR
SUPPLIER "A"

TEST PROGRAM FOR THE POLYIMIDE GLASS LAMINATE
(TL-GI 010 C1/0 A1) VENDOR SAMPLE "A"

Test No.	Specification	Para.	Requirement	Test Value or Observation	Con-form-ance	Non Con-form-ance
1	Mil-P-55617B	3.3.1	Machinability – Drilled, punched sawed, & machined in all directions with no cracking splitting or other degradation.	Drilled, sheared, sawed with no degradation using normal production techniques. Extreme abuse in drilling produced a separation of the resin from glass fibers.	x	
2	"	3.3.2	Pits and Dents. No more than 30 points per schedule in spec.	Both single and double clad.	x	
3	"	3.3.3	Scratches. No larger than 140 micro-inches	No scratches greater than 140 micro-inches (see surface finish)	x	
4	"	3.3.4a	Dimensions and Tolerances. No more than 1 inch variation from standard size and ±.062 from ordered size.	Sheet sizes 36" x 48", variation less than .062 in. Except one sheet was 6" short in the length dimension.		x
5	"	3.3.4b	Single Clad: Thickness Tolerance ±.002" Nominal .0114"; Double Clad: .0128"	Single Clad: Avg measured .0108"; Double Clad: Avg measured .0119"	x	
6	"	3.3.5	Color – Natural – typically light to dark brown	Single Clad: Brown – Borders exhibited darker shade; Double Clad: Uniform brown color (see Exhibit 3)	x	

TEST PROGRAM FOR THE POLYIMIDE GLASS LAMINATE
(TL-GI 010 C1/0 A1) VENDOR SAMPLE "A"

Test No.	Specification	Para.	Requirement	Test Value or Observation	Con-form-ance	Non Con-form-ance
7	Mil-F-55561	3.3.6.1	Copper Purity	99.87%	x	
			Foil Thickness	Single Clad Avg. .00122" / Double Clad Avg. .00125"		
8	Mil-P-55617B	3.4	Surface Finish – 20 micro inches max.	Avg for all samples 7 micro inches	x	
9	"	3.5	Solder Dip – withstand a 20 second dip in 500°F solder sustaining no de-lamination or other degradation	No degradation sustained to foil, laminate, or surface (fluxed or unfluxed) Both single and double clad	x	
10	Mil-P-55617B	3.52	Etched Specimen No residual copper greater than .005 inch dia.	No residual copper Both single and double clad	x	
11	"	3.8	Marking per Mil-Std-130 two labels	One label	Acceptable at this time	
12	"	3.9	Workmanship-free of wrinkles, blisters cracks & other defects.	Single Clad Panel edges exhibited large amount of curl. One foot squares cut from the sheet had a 5.8" vertical displacement.		x
				Double Clad Flat, smooth, no scratches, no curl	x	

TEST PROGRAM FOR THE POLYIMIDE GLASS LAMINATE
(TL-GI 010 C1/0 A1) VENDOR SAMPLE "A"

Test No.	Specification	Para.	Requirement		Test Value or Observation		Conformance	Non Conformance
13	Mil-P-55617B	3.6 Table III	Peel Strength (Min)		Single Clad	Double Clad		
			As etched	5 lb	5.1	6.9	x	
			After solder dip	5 lb	5.3	7.1	x	
			After thermal cycling	5 lb	4.9	7.7	x	
			After elevated temp	5 lb	5.0	7.4	x	
			After exposure to plating Sol	5 lb	5.6	5.5	x	
			At elevated temp	5 lb	3.9	5.1	x	
14	"	"	Coefficient of thermal Expansion Z Axis Max 70 Micro inches between 25°C – 240°C		Below glass transition temp measured in inches x 10^{-6}/°C 58.9 Avg of 6 trials		x	
					1st Trial	2nd Trial		
15	"	"	Volume resistivity C-96/35/90-6×10^4 meg ohm min		1.1×10^6 meg ohm	6.5×10^7 meg ohm	x	
			E-24 @ temp 6×10^4 meg ohm @ 204°C min		1.7×10^7 meg ohm	3.7×10^7 meg ohm	x	
16	"	"	Surface Resistivity					
			C-96/35/90 6×10^4 meg ohm min		1.3×10^4 " "	1.5×10^6 " "	x	
			E-24 @ temp 6×10^4 meg ohm min		3.1×10^4 " "	8.6×10^4 " "	x	
17	"	"	Dimensional stability		Single Clad			
			After etching	.0005"/in	Largest value	.00028"/in	x	
			After elevated temp	.0005"/in	" "	.00059		x
			After temp cycling	.0003"/in	" "	.00062		x
					Double Clad			
			After etching			.00023	x	
Note:	Peel strengths represent lowest avg.		After elevated temp			.00029	x	
			After temp cycling			.00026	x	

TEST PROGRAM FOR THE POLYIMIDE GLASS LAMINATE
(TL GI 010 C1/0 A1) VENDOR SAMPLE "A"

Test No.	Specification	Para.	Requirement	Test Value or Observation	Conformance	Non Conformance
18	Mil P 55617B	3.6 Table III	Electric Strength 750 volts/Mil Min	Min value 860 Volts/Mil Min	x	
19	"	"	Dielectric Constant At 1 MHz Max 4.8	Max value 4.69	x	
20	"	"	Dissipation Factor @ 1 MHz Max .025	Max value .020	x	
21	"	"	Arc Resistance Min seconds 120	Min value .121 Sec.	x	
			TESTS IN ADDITION TO MIL-P-55617B			
22	ASTM-D 568 UL 94 V1	V-1	FLAMABILITY cannot burn more than 30 sec. cannot burn to clamp (4 3/4") cannot drip flaming particles no glowing combustion beyond 60 seconds after 2nd removal	22.1 sec max Burn length 4.0 in No dripping None beyond 19.2 sec.	x	

TEST PROGRAM FOR THE POLYIMIDE GLASS LAMINATE
(TL-GI 010 C1/0A1) VENDOR SAMPLE "A"

Test No.	Specification	Para.	Requirement	Test Value or Observation	Conformance	Non Conformance
23	ASTM-D-790		FLEXURAL STRENGTH 50×10^3 PSI @ 25°C min	49×10^3 PSI @ 25°C (Value represents the minimum, the avg. value was above the minimum)		x
24	ASTM-D-790		FLEXURAL MODULUS 4×10^3 PSI @ 25°C min	3.3×10^6	x	
25	Mil-Std-202 Method 302		Insulation Resistance 100 Meg Ohm	Volume resistivity Performed in place of		
26	Mil-E-5272/1		Fungus Resistance No nutrient	No growth, no nutrient	x	
27	ASTM-G-2369		Weather Resistance Two weeks exposure in weatherometer + ASTM-D-790	Flexural strength 59.3×10^3 Flexural Modules 3.5×10^6 PSI No visual degradation	x	
28			Thermal Conductivity	5.7×10^{-4} cal-cm/sec-cm^2-°C		
29			Absolute Max Temp - 204°C Checked peel strengths and electric strength at 50°F increments	Low peel strength values (single clad) Electric strength excellent		
30			Max continuous temp - 150°C Checked peel strengths and electric strengths at 50°F increments after 4 hrs at temp	Low peel strength values (single clad) Electric strength excellent		

TEST PROGRAM FOR THE POLYIMIDE GLASS LAMINATE
(TL-GI 010 C1/0 A1) VENDOR SAMPLE "A"

Test No.	Specification	Para.	Requirement	Test Value or Observation		Con-form-ance	Non Con-form-ance
31	ASTM-G-2369		Low temp embrittlement Measured flexural Strength and flexural Modulus from -80°C to +60°C in 10° increments	Flexural strength Ranged from 80.3×10^3 PSI To 62.0×10^3 PSI Flexural modulus Ranged from 3.8×10^6 to 3.6×10^6 PSI			
32	ASTM-D-638		Tensile Strength 40×10^3 PSI Min	29,669 PSI sample only .010 thick			x
33	ASTM-D-570		Water absorption 3% max	.22%		x	
34			Abrasion resistance, taber abrader CS-17 wheel, 1000 gm load 1000 cycles	Weight loss 10.6 mg			
35			Chemical Exposure	Condition	Peel Strength		
			Methylene chloride	No degradation	6.4 lb min	x	
			20% Ammonium persulfate	" " removed cu		x	
			30% Nitric acid	Slight darkening removed cu		x	
			50% Acetic Anaydride	No degradation		x	
			2N Sodium Hydroxide	" "	6.2 lb min	x	
			Trichlorethylene	" "		x	
			Freon TE 35	" "		x	
			Methylethyl Ketone	" "	6.8 lb min	x	
			Allied Cold Strip	" "	6.0 lb min	x	

Note: Peel strengths represent avg values for 4 strips

EXHIBIT 25
COMPILATION OF TEST RESULTS
FOR
SUPPLIER "F"

TEST PROGRAM FOR THE POLYIMIDE GLASS LAMINATE
(TL GI 010 C1/0 A1) VENDOR SAMPLE "F"

Test No.	Specification	Para.	Requirement	Test Value or Observation	Con form ance	Non Con form ance
1	Mil P 55617B	3.3.1	Machinability - Drilled, punched sawed, & machined in all directions with no cracking, splitting or other degradations.	Drilled, sheared, sawed with no degradation using normal production techniques. Extreme abuse in drilling produced a separation of resin from glass fibers.	x	
2	"	3.3.2	Pits and Dents - No more than 30 points per schedule in spec.	Both single & double clad	x	
3	"	3.3.3	Scratches - No larger than 140 micro-inches	No scratches greater than 140 micro-inches. (See surface finish.)	x	
4	"	3.4.4a	Dimensions and Tolerances - No more than 1 inch variation from Std size and +.062	Sheet size 36" x 48" variation less than .062 inch.	x	
5	"	3.3.4.b	Thickness Tolerance +.002" Nominal .0114	Single Clad Double Clad Avg. measured .0118" .0131"	x	
6	"	3.3.5	Color - Natural Typically light to dark brown	Light Brown – not much variation Both single and double clad	x	

TEST PROGRAM FOR THE POLYIMIDE GLASS LAMINATE
(TL-GI 010 C1/0 A1) VENDOR SAMPLE "F"

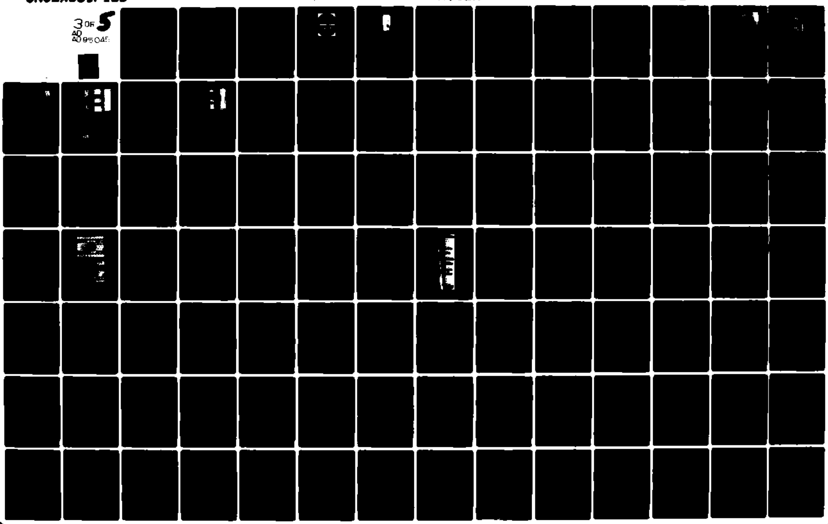
Test No.	Specification	Para.	Requirement	Test Value or Observation	Con-form-ance	Non Con-form-ance
7	Mil-F-55561	3.3.6.1	Copper Purity	99.71	x	
			Foil Thickness	Single Clad: Avg. .00115"; Double Clad: Avg. .0112 – some areas .0010"		x
8	Mil-P-55617B	3.4	Surface Finish 20 micro-inches max	Avg. for all samples – 11 micro-inches	x	
9	"	3.5	Solder Dip – Withstand a 20 second dip in 500°F solder sustaining no delamination or other degradation.	No degradation sustained to foil, laminate or surface (fluxed or unfluxed) Both single and double clad	x	
10	"	3.5.2	Etched Specimen – No residual copper greater than .005 inch dia.	No residual copper Both single and double clad	x	
11	"	3.8	Marking per Mil-Std-130 Two Labels	One Label	Acceptable at this time	
12	"	3.9	Workmanship – Free of wrinkles, blisters cracks and other defects	Panels were uniform and workmanship was good Both single and double clad	x	

(TL-GI 010 C1/0 A1) VENDOR SAMPLE "F"

Test No.	Specification	Para.	Requirement	Test Value or Observation		Con-form-ance	Non Con-form-ance
13	Mil-P-55617B	3.6 Table III	Peel Strength (Min)	Single Clad	Double Clad		
			As etched 5 lb	4.8	10.7	x	
			After solder dip 5 lb	3.7	10.8	x	
			After thermal cycling 5 lb	4.9	10.7	x	
			After elevated temp 5 lb	4.9	10.6	x	
			After exposure to plating sol 5 lb	4.4	11.1	x	
			At elevated temp 5 lb	3.9	7.6	x	
	"	"	Coefficient of thermal Expansion Z axis Max 70 micro inches between 25°C – 240°C	Below glass transition temp Measured in inches x 10^{-6}/°C 69.1 avg. of 3 trials		x	
				1st Trial	2nd Trial		
15	"	"	Volume resistivity				
			C-96/35/90 6×10^4 meg ohm min	3.2×10^7 meg ohm	2.5×10^8 meg ohm	x	
			E-24 @ temp 6×10^4 meg ohm @ 204°C min	3.4×10^7 meg ohm	2.7×10^7 " "	x	
16	"	"	Surface resistivity				
			C-96/35/90 6×10^4 meg ohm min	1.9×10^4 " "	1.6×10^6 " "	x	
			E-24 @ temp " " " " @ 204°C	4.5×10^4 " "	4.8×10^6 " "	x	
17	"	"	Dimensional Stability	Single Clad			
			After etching .0005"in	Largest value .00019"/in		x	
			After elevated temp .0005"/in	Largest value .00027"/in		x	
			After temp cycling .0003"/in	Largest value .00024"/in		x	
				Double Clad			
			After etching	.00031"		x	
			After elevated temp	.00048"		x	
			After temp cycle	.00046"			x

AD-A095 045 GENERAL DYNAMICS CORP POMONA CA POMONA DIV F/G 9/5
RIGID-FLEX PRINTED CIRCUIT MANUFACTURING PROCESS. A PROJECT OF --ETC(U)
JUN 79 J A REAVILL N00123-77-C-1192
UNCLASSIFIED NAVSEA-MT-S-479-77 NL

3 OF 5
AD
A095045



TEST PROGRAM FOR THE POLYIMIDE GLASS LAMINATE
(TL GI 010 C1/0 A1) VENDOR SAMPLE "F"

Test No.	Specification	Para.	Requirement	Test Value or Observation	Con-formance	Non Con formance
18	Mil-P 55617B	3.6 Table III	Electric Strength 750 volts/Mil Min	Min value 1040 volts/Mil Min	x	
19	"	"	Dielectric Constant At 1 MII^2 Max 4.8	Max value 4.44	x	
20	"	"	Dissipation Factor @ 1 MII_2 Max .025	Max value .016	x	
21	"	"	Arc Resistance Min seconds 120	Min value 124 sec	x	
			TESTS IN ADDITION TO MIL-P-55617B			
22	ASTM D-568 UL 94-V1		Flamability - cannot burn more than 30 sec - cannot burn to clamp (4-3/4)" - cannot drip flaming particles - no glowing combustion beyond 60 seconds after 2nd removal	18.6 sec max Burn length 4.0 in No dripping None beyond 18.6 sec.	x	

TEST PROGRAM FOR THE POLYIMIDE GLASS LAMINATE
(TL-GI 010 C1/0 A1) VENDOR SAMPLE "F"

Test No.	Specification	Para.	Requirement	Test Value or Observation	Conformance	Non Conformance
23	ASTM-D-790		Flexural Strength 50 x 103 PSI @ 25°C min	63.2 x 10^3 PSI @ 25°C	x	
24	ASTM-D-790		Flexural Modulus 4 x 10^3 PSI @ 25°C	2.8 x 10^6	x	
25	Mil Std 202 Method 302		Insulation Resistance 100 meg ohm	Volume resistivity performed in place		
26	Mil-E-5272/1		Fungus Resistance No nutrient	No growth, no nutrient	x	
27	ASTM-G-2369		Weather Resistance			
			Two weeks exposure in weather-ometer + ASTM-D-790	Flexural strength 51.9 x 10^3 PSI Flexural modulus 2.6 x 10^6 PSI No visual degradation	x	
28			Thermal Conductivity	4.8x10^{-4} cal-cm/sec-cm^2-°C		
29			Absolute Max Temp - 204°C Checked peel strengths and electric strength at 50°F increments	*Low peel strength values (single clad)* Electric strength excellent		
30			Max continuous temp - 150°C Checked peel strengths and electric strengths at 50°F increments after 4 hrs at temp	Low peel strength values (single clad) Electric strength excellent		

TEST PROGRAM FOR THE POLYIMIDE GLASS LAMINATE
(TL-GI 010 C1/0 A1) VENDOR SAMPLE "F"

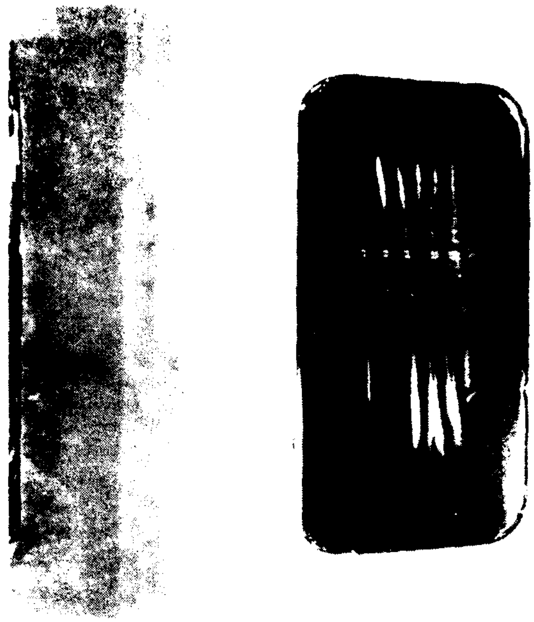
Test No.	Specification	Para.	Requirement	Test Value or Observation		Con-form-ance	Non Con-form-ance
31			Low temp embrittlement Measured flexural strength and flexural modulus from -80°C to +60°C in 10° increments	Flexural strength range from 74.6×10^3 to 62.3×10^3 PSI Flexural modulus ranged from 3.0×10^6 to 2.8×10^6 PSI			
32	ASTM-D-638		Tensile Strength 40×10^3 PSI min	28,081 PSI sample only .010" thick			x
33	ASTM-D-570		Water absorption 3% max	.25%			
34			Abrasion resistance Taber Abrader CS-17 wheel, 1000 gm load 1000 cycles	Weight loss 13.7 mg		x	
35			Chemical Exposure	Condition	Peel Strength		
			Methylene Chloride	No degradation	10.2 lb min	x	
			20% ammonium persulfate	" " removed cu			
			30% Nitric acid	Slight discoloration		x	
				removed cu		x	
			50% Acetic Anaydride	No degradation,		x	
			2N Sodium Hydroxide	" "	6.2 lb min	x	
			Trichlorethylene	" "		x	
			Freon TE 35	" "		x	
			Methylethyl Ketone	" "	6.8 lb min	x	
			Allied Cold Strip CB-XNT	" "	6.0 lb min	x	

Note: Peel strengths represent avg. values for 4 strips

MAGNIFICATION 30X

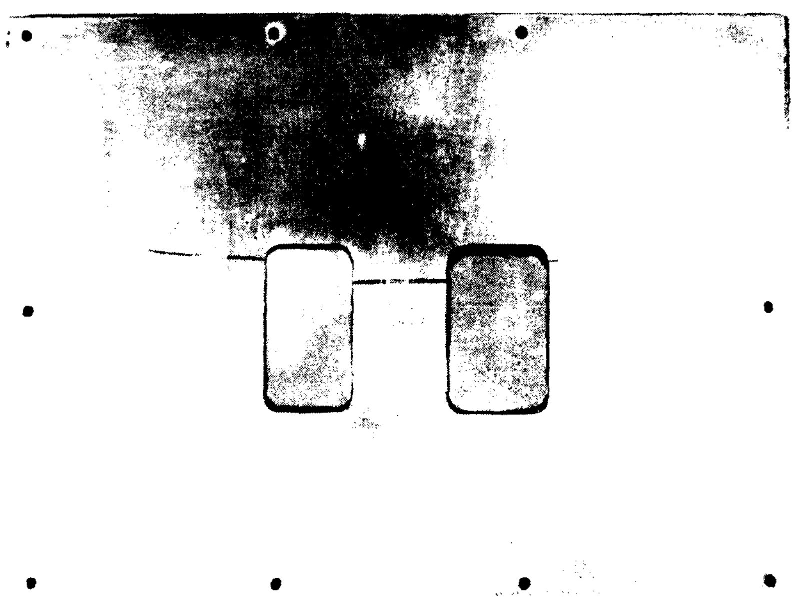
EXHIBIT 26

Plated-through-hole structure. This sample shows a single plated-through hole and corresponding inner conductors. Not all of the glass fibers were removed but the barrel and attachment of inner conductors visually is acceptable.



R201694

Portion of a rigid-flex panel showing a wrinkled window area. An inadequate window pad was used and did not provide proper pressure.



R201693

Eight-layer rigid-flex cable in the panel form showing a crack in the polyimide rigid board area.

EXHIBIT 27

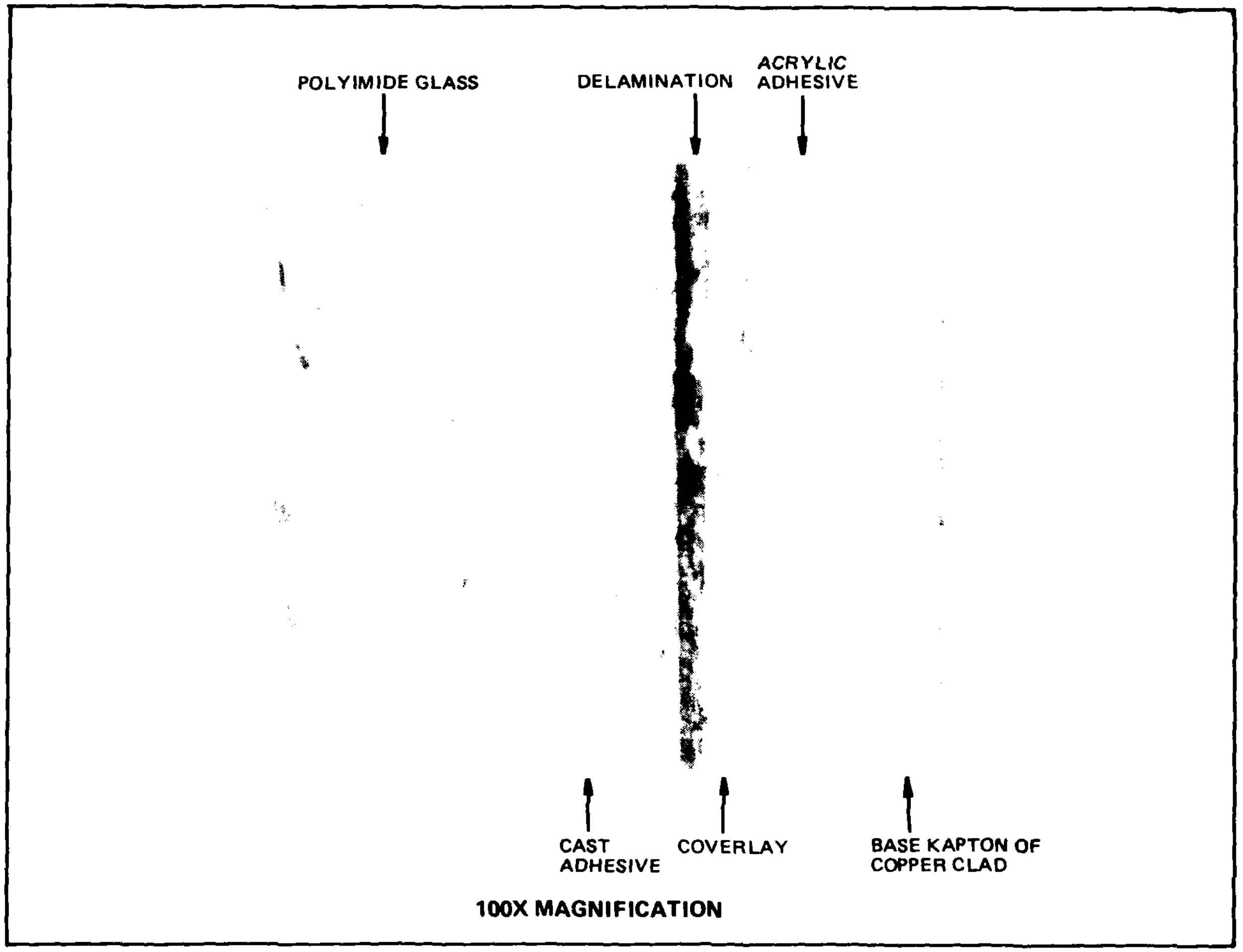
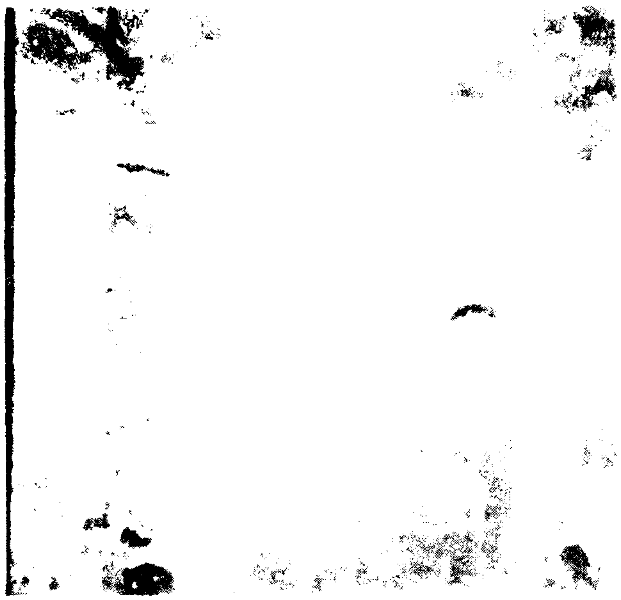
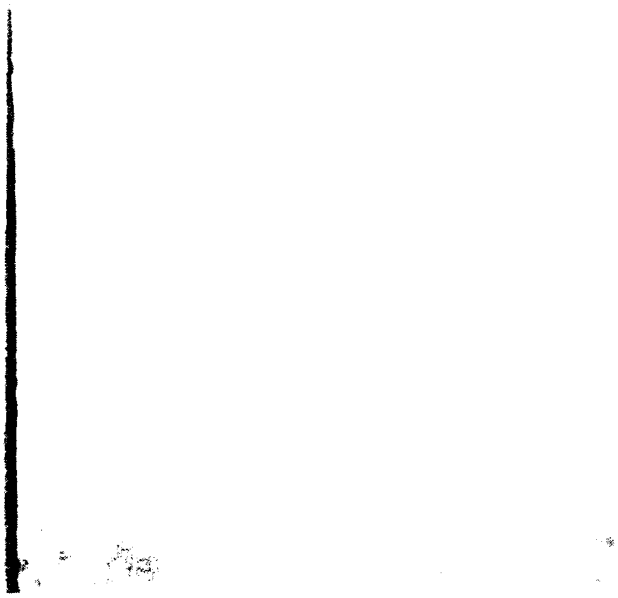


EXHIBIT 28. Cross section of delaminated cast adhesive from coverlay in cable 2. No definite sign of a *release film* is *evident in this photo*.



A. 500X MAGNIFICATION

B. 5,000X MAGNIFICATION



C. 20,000X MAGNIFICATION

EXHIBIT 29. Delamination of the area of the coverlayer which had been laminated to the stiffener.

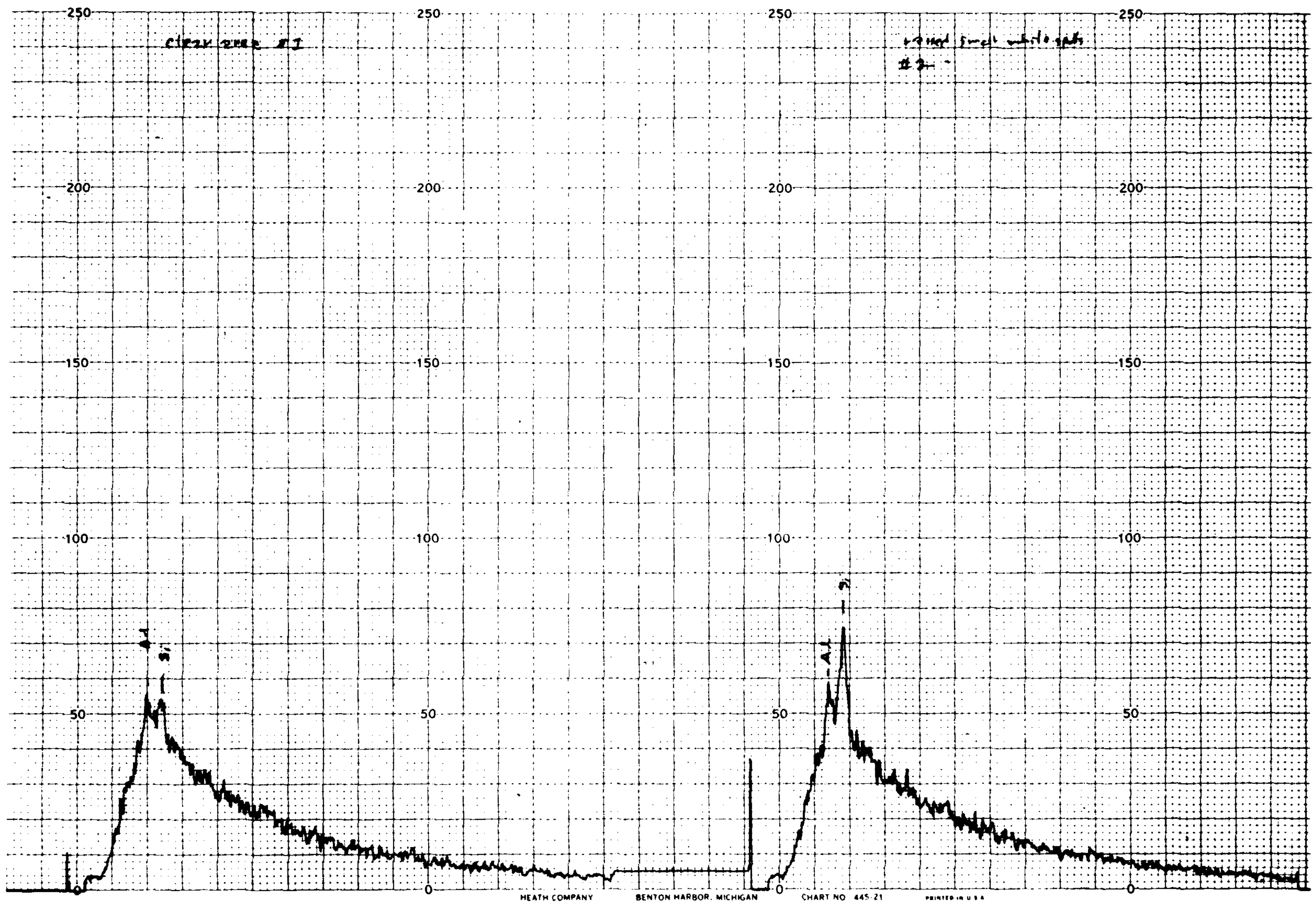


EXHIBIT 30. Graphic illustration of an x-ray scan of the surface of the samples used in Exhibit 29. The area showing high silicon content is that which appears to be a coating.

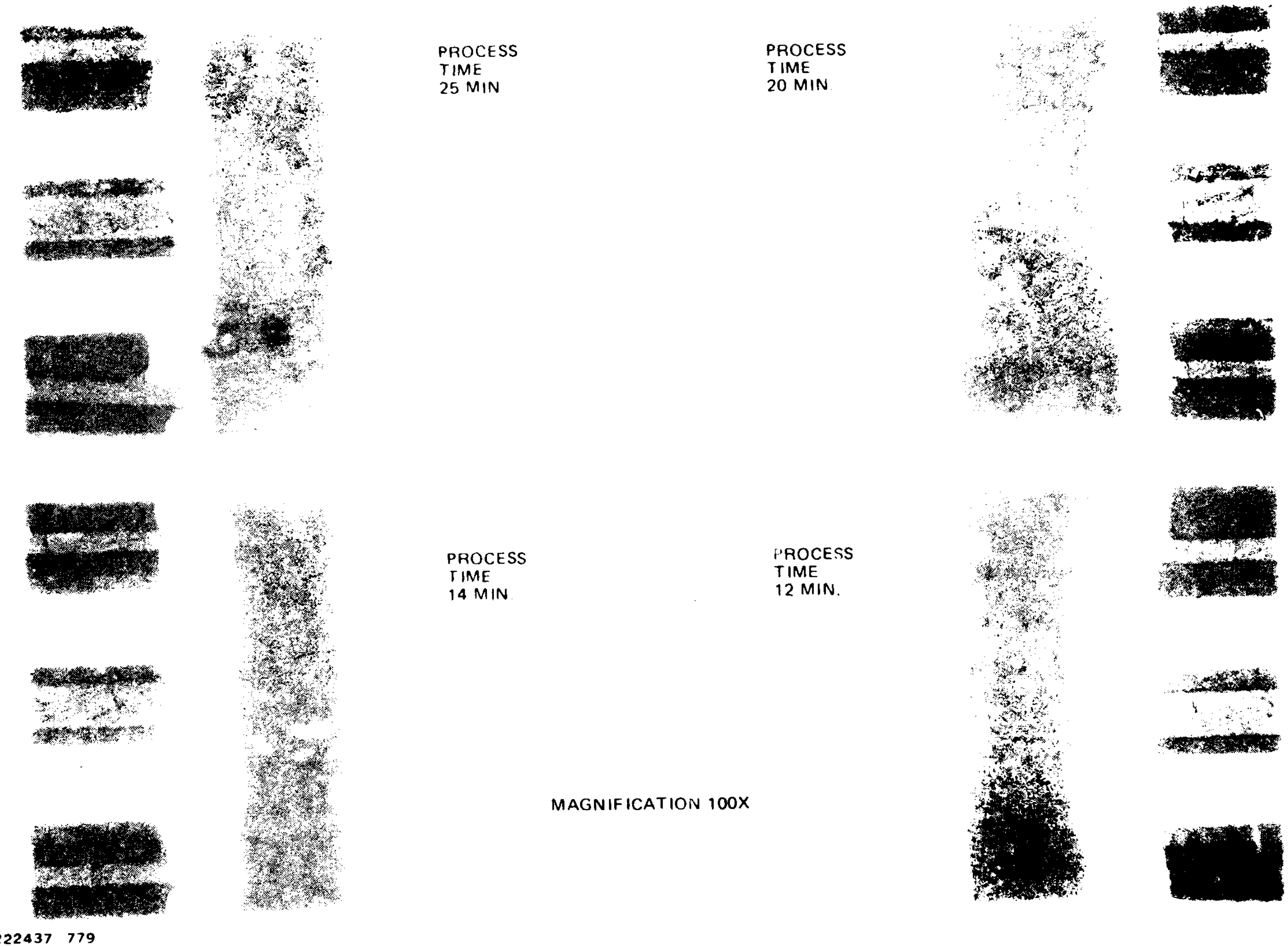


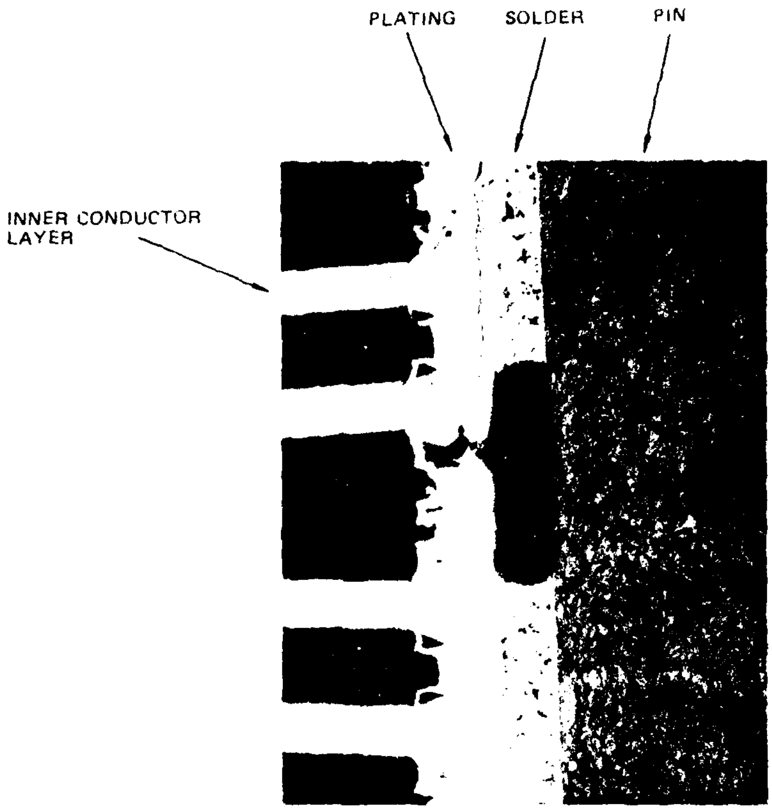
EXHIBIT 31. Several degrees of etch back on a rigid-flex cable which was processed in a dry gas plasma drill smear removal operation.

A222440

EXHIBIT 32. Mask Used in Plasma Drill Smear Removal.

R206565

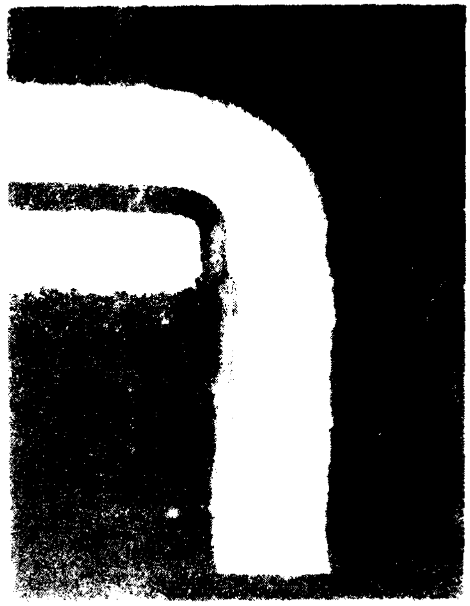
EXHIBIT 33. Panel CR-2 plated for one hour at 1/2 current density, and one hour at full current density.



R201695-1 7108

EXHIBIT 34. Shows how a plating void can outgas and rupture the plated-through-hole wall during soldering.

BREAK AND SEPARATION IN
ELECTROLESS COPPER PLATING

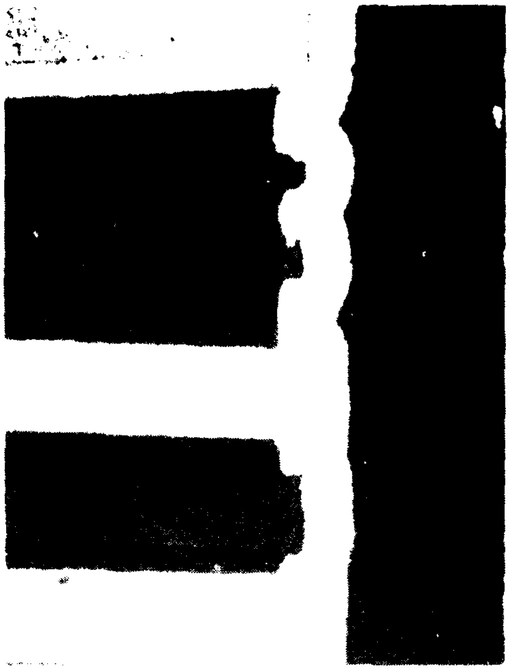


CRACK IN ELECTROLESS
COPPER PLATING

300 X MAGNIFICATION SEPARATION IN ELECTROLESS COPPER PLATING

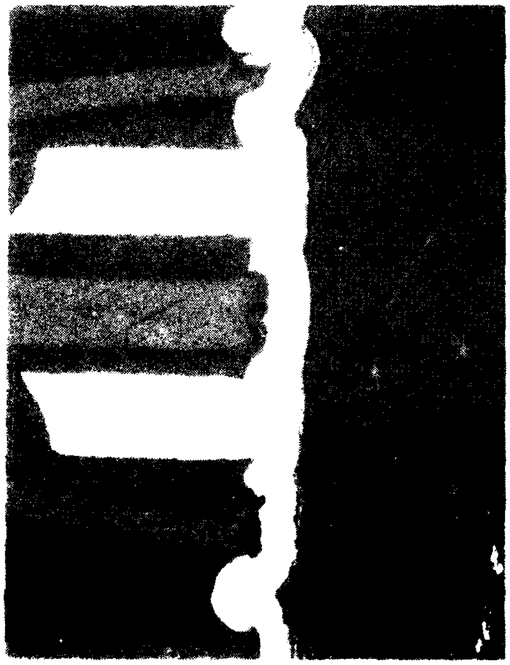
R203271

EXHIBIT 35. Microsections showing cracks and separations which appeared in an epoxy fiberglass panel plated in the first high-speed room temperature bath evaluated.



2 HRS YIELDED
APPROXIMATELY 200 μ IN.

1 HR YIELDED
APPROXIMATELY 100 μ IN.

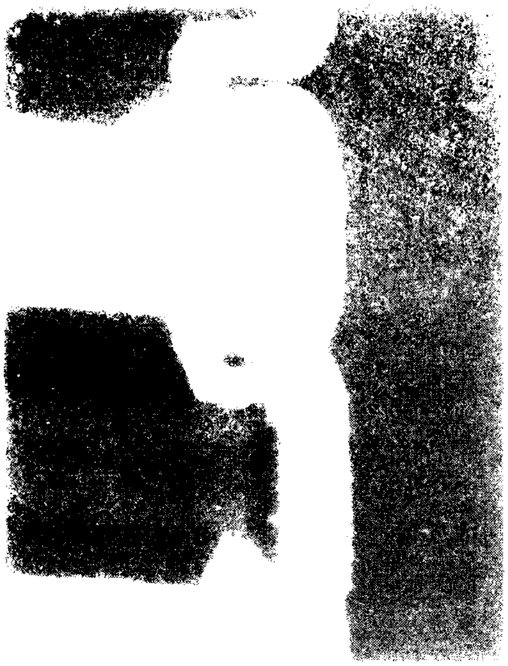


½ HR YIELDED LESS THAN 100 μ IN.

NOTE: NO VOIDS WERE EVIDENT ON ANY OF THE SAMPLES, BUT IT MUST BE OBSERVED THAT THE ETCH BACK IS ALSO LESS SEVERE WHICH ACCOUNTS FOR THIS PHENOMINA (RECESSES WERE TYPICALLY 500 – 800 μ IN. DEEP).

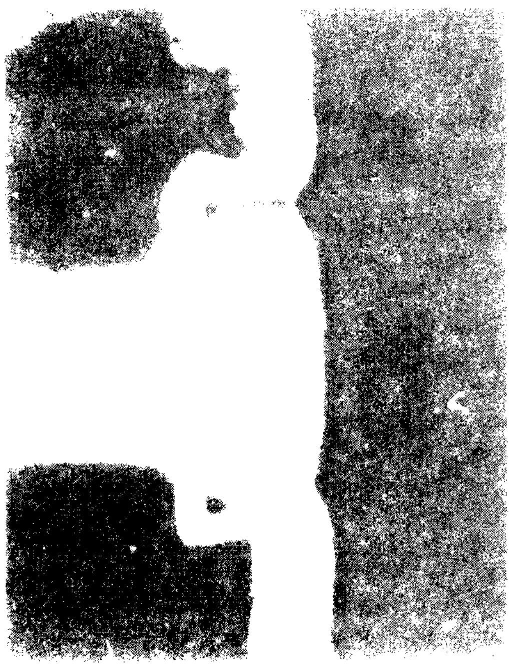
A209675-1

EXHIBIT 36. Shows Electroless Copper Thicknesses of a Type 2 Bath Using Various Immersion Times.



2 HRS YIELD 250 μ IN.

1½ HRS YIELDS 200 μ IN.



1 HR YIELDS 150 μ IN.

NOTE: MOST HOLES EXHIBITED GROSS PLATING VOIDS AND SEEM TO BE CAUSED BY DEEP RECESSES ETCHED-BACK IN THE HOLE WALLS. RECESSES RANGE FROM 1500 – 1700 μ IN. DEEP.

A209676-1

EXHIBIT 37. Shows Electroless Copper Thicknesses of a Type 4 Bath using Various Immersion Times.

SAMPLE HAS VOID IN COPPER PLATING – PLATED USING DIRECT CURRENT

SAMPLE HAS VOID IN COPPER PLATING – PLATED USING 50% DUTY CYCLE

R209677

EXHIBIT 38. Two Photomicrographs Showing That Both Pulse-Plated Samples and Direct Current-Plated Samples can Contain Voids.

Note: The shape of these voids is narrower at the entrance.

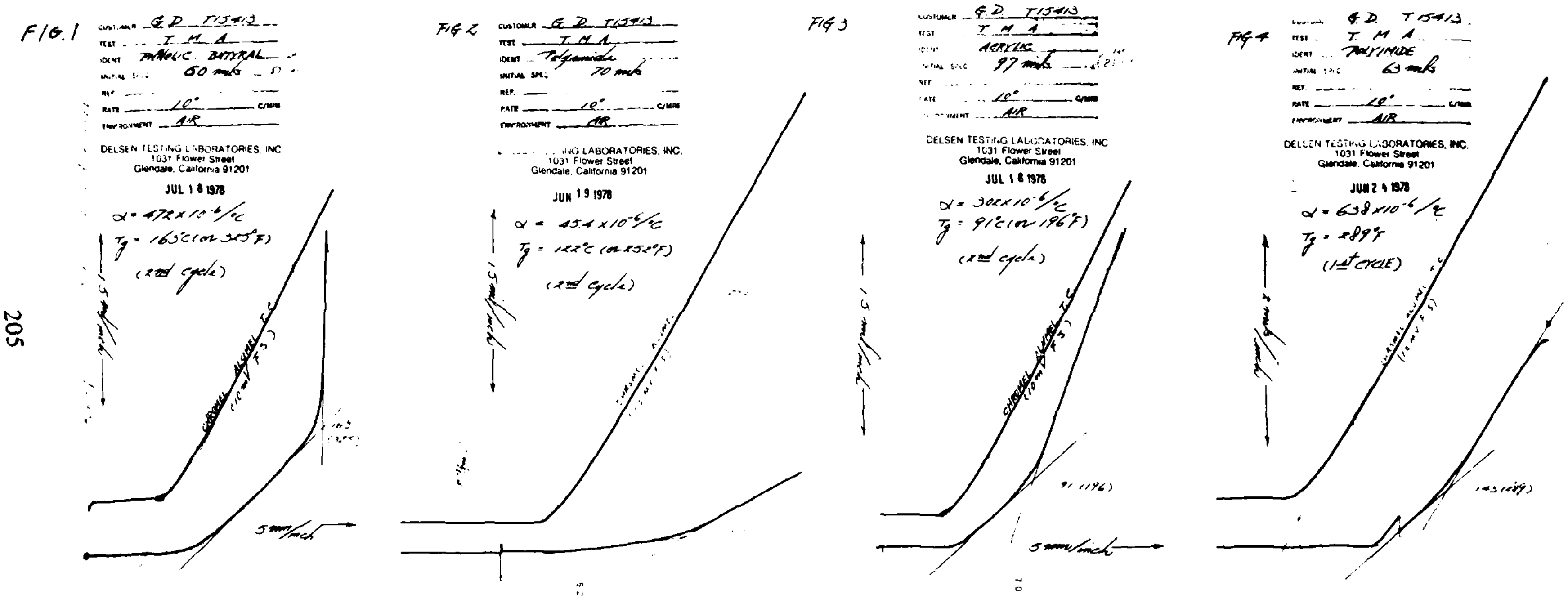
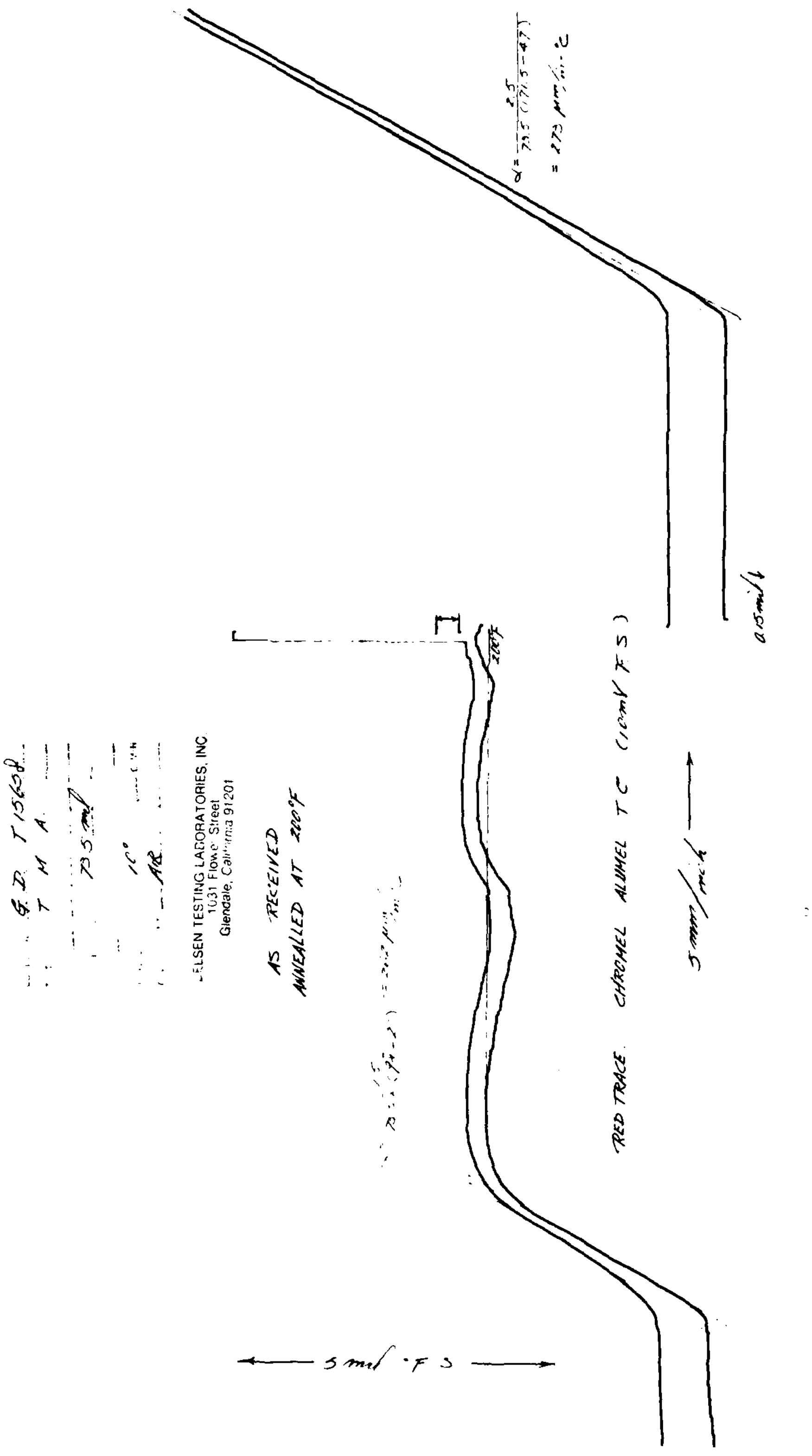
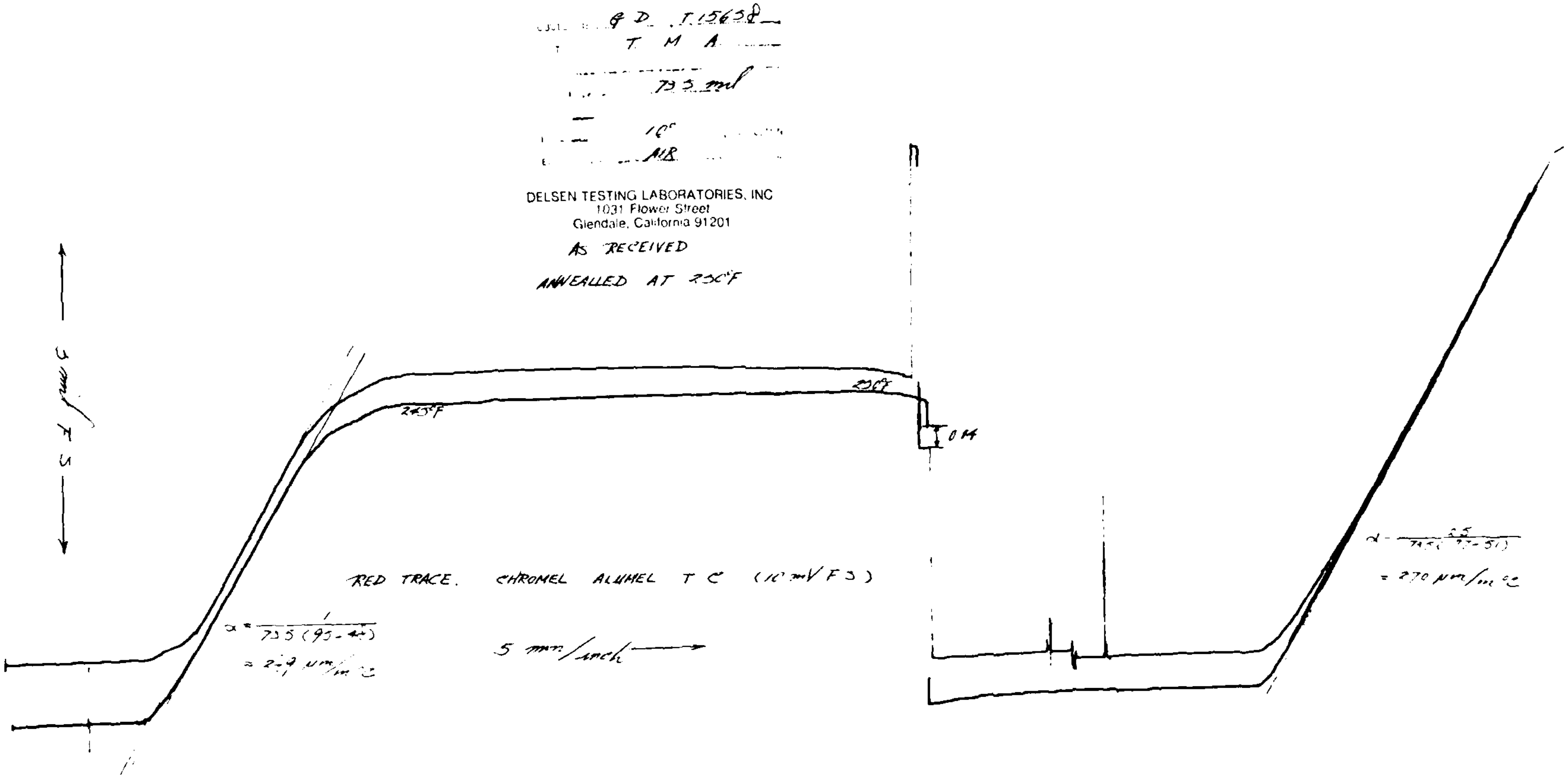
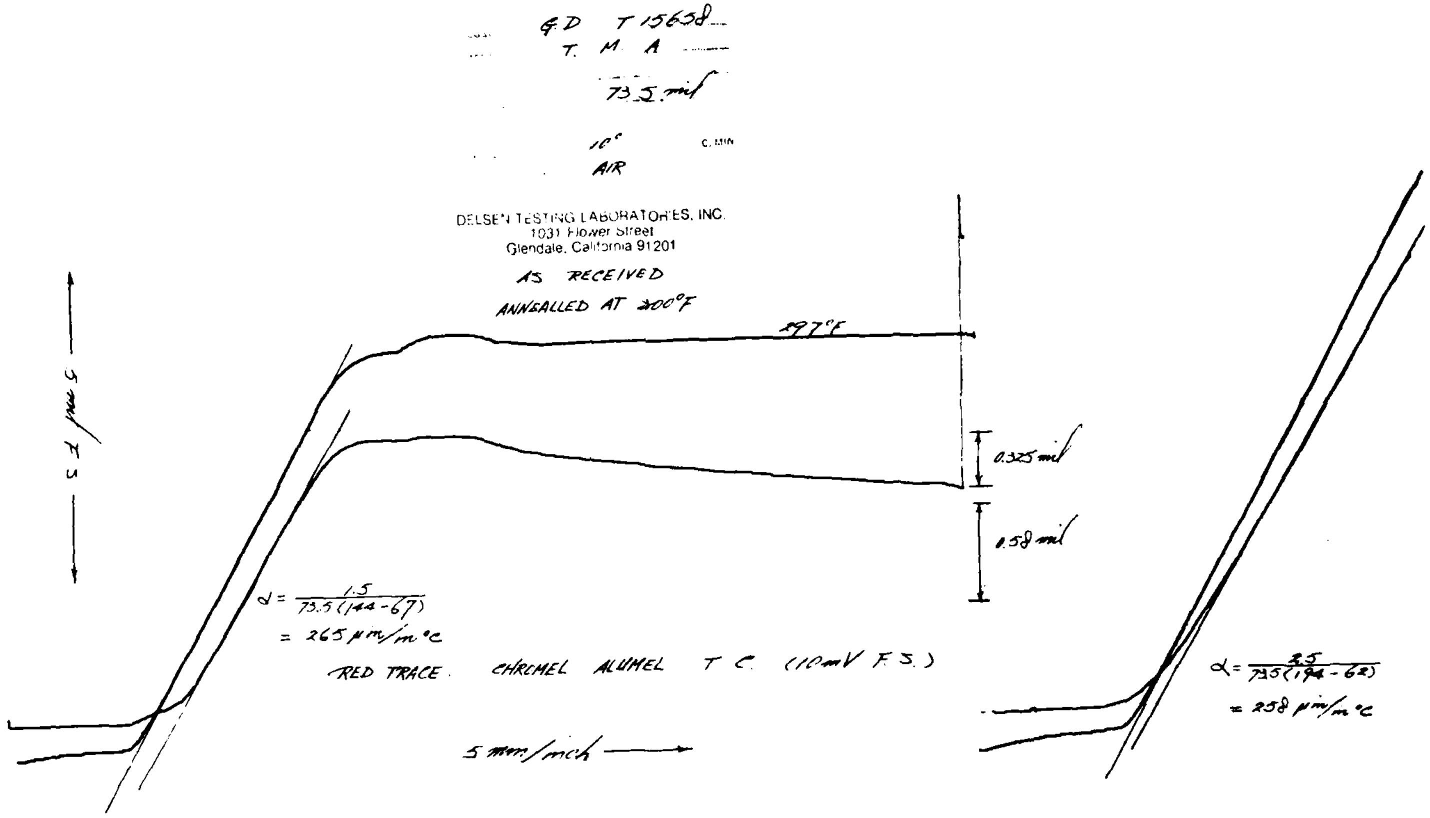


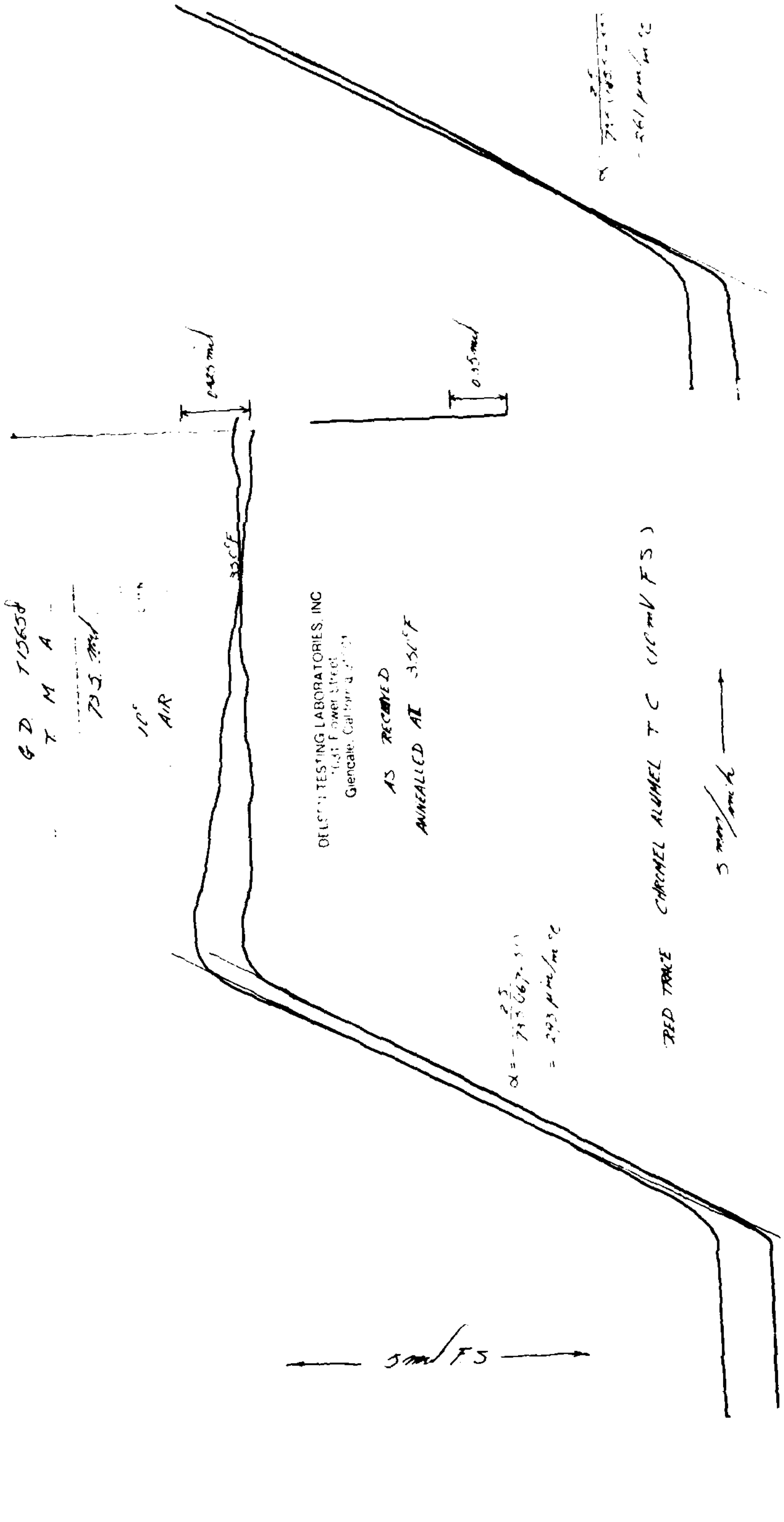
EXHIBIT 39. T.M.A. Curves for Adhesive Films.

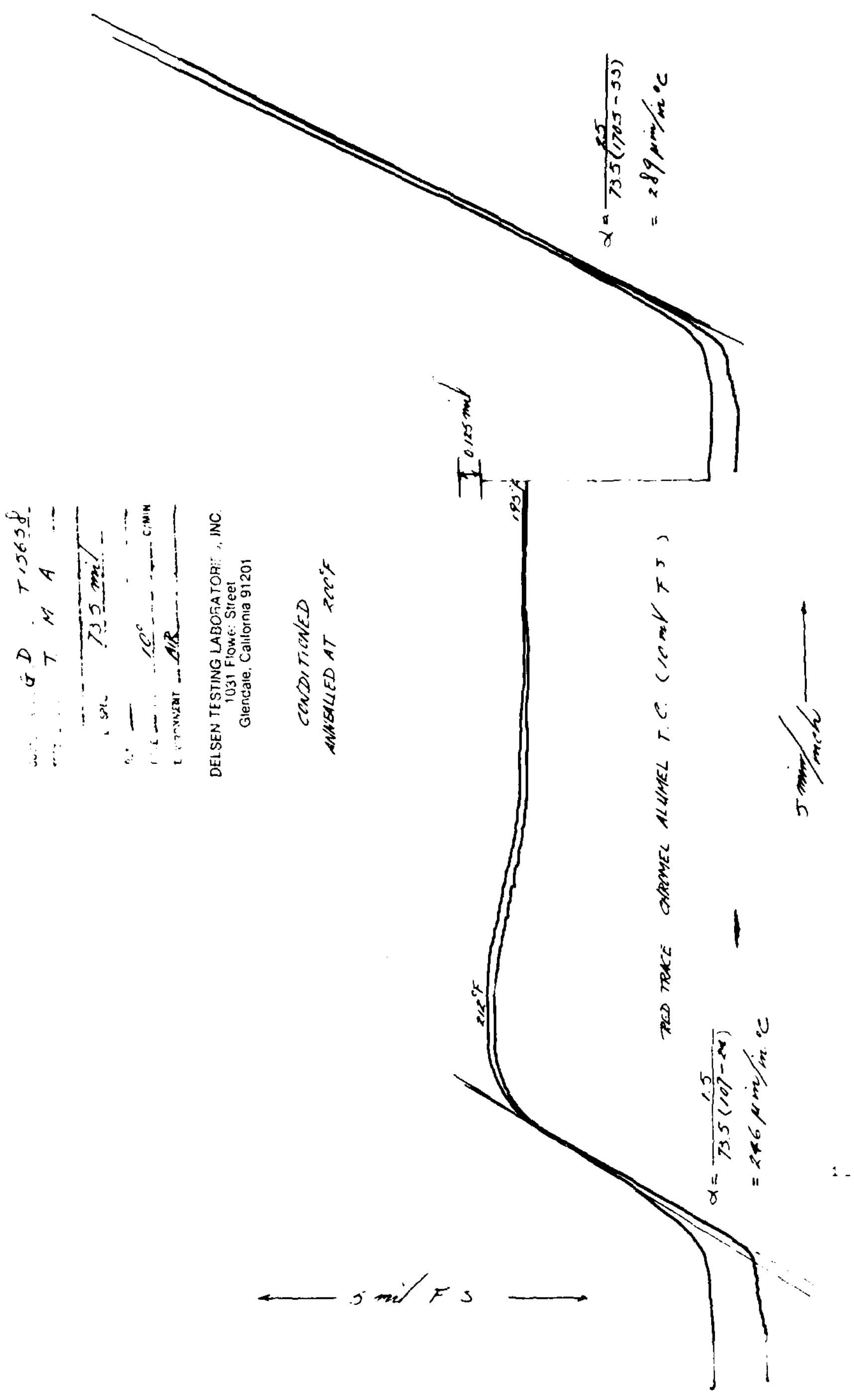
EXHIBIT 40
T.M.A. CURVES FOR POLYIMIDE
RIGID-FLEX CABLES HEATED TO 350°F

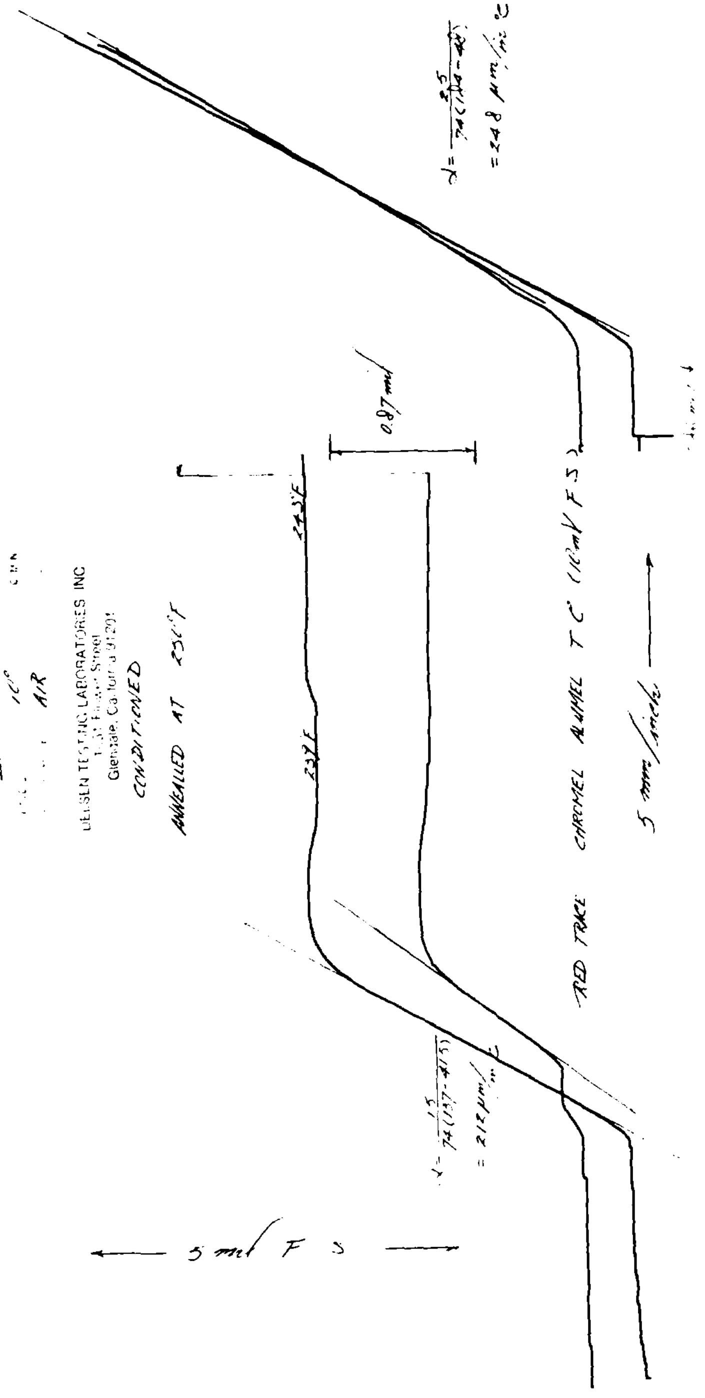

ELSEN TESTING LABORATORIES, INC
1031 Flower Street
Glendale, California 91201
AS RECEIVED
ANNEALLED AT 220°F
RED TRACE CHROMEL ALUMEL T C (10mV F S)
5 mil F S

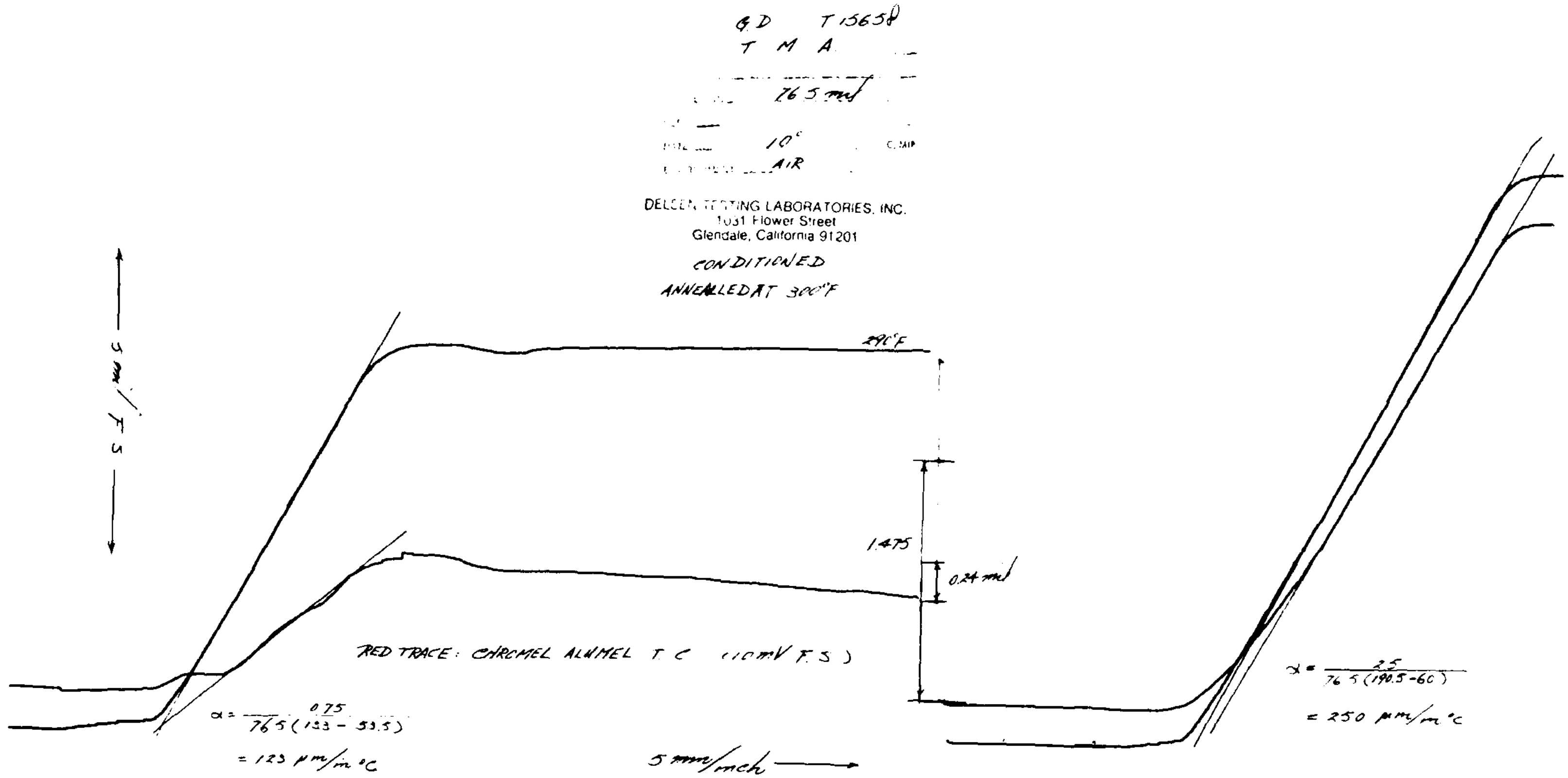

G.D. T.15658
T M A
73.5 mil
10°
MB
DELSEN TESTING LABORATORIES, INC
1031 Flower Street
Glendale, California 91201
AS RECEIVED
ANNEALLED AT 250°F
5 mil F S
250°F
245°F
0.14
RED TRACE. CHROMEL ALUMEL T C (10 mV F S)
5 mm/inch
= 270 μm/m °C

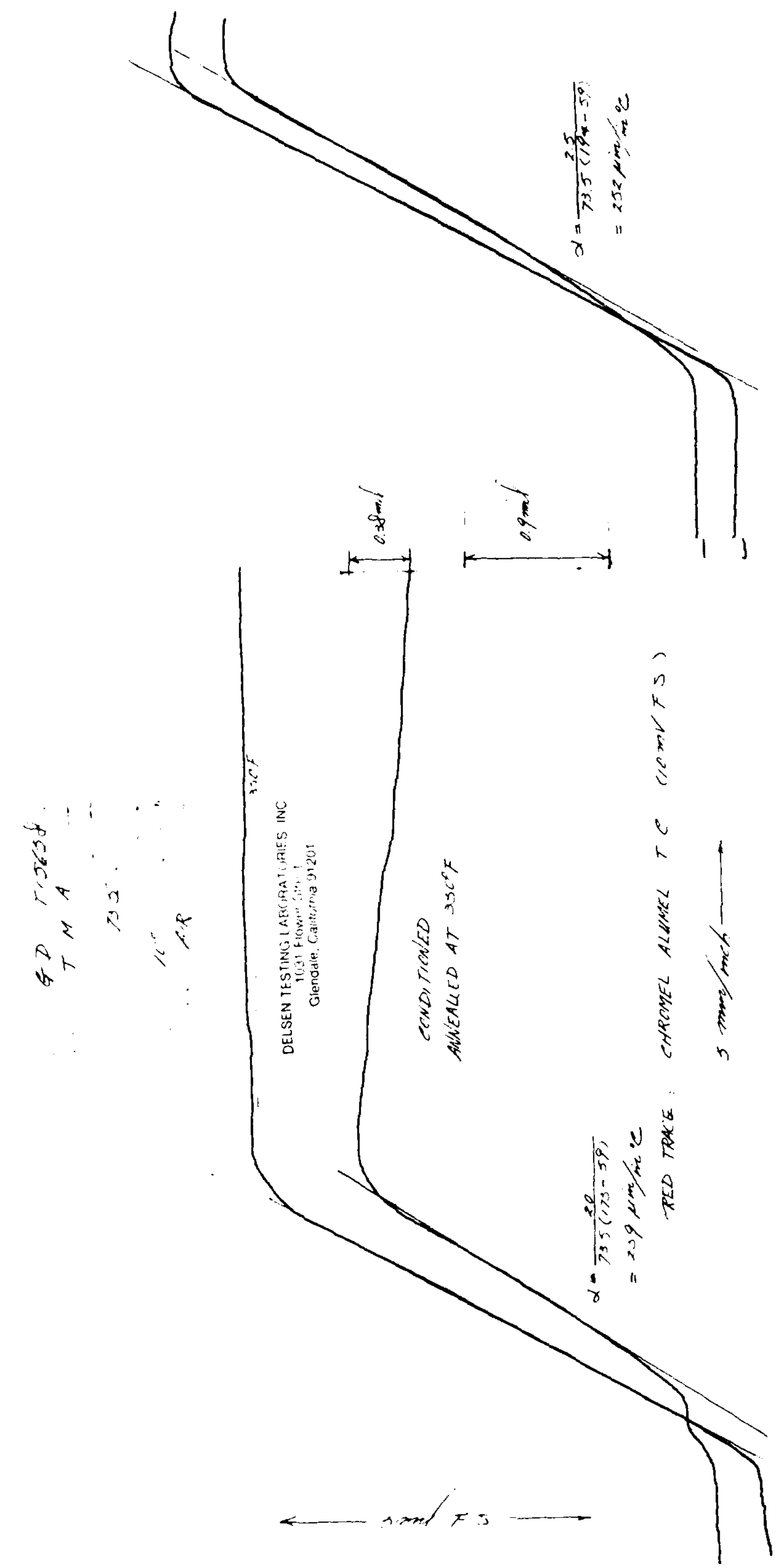

G.D T 15658
T. M. A
73.5 mil
10° C/MIN
AIR
DELSEN TESTING LABORATORIES, INC.
1031 Flower Street
Glendale, California 91201
AS RECEIVED
ANNEALLED AT 200°F
297°F
0.325 mil
1.58 mil
5 mil F.S.
α = 1.5 / 73.5 (144 - 67)
= 265 μm/m °C
RED TRACE. CHROMEL ALUMEL T.C. (10mV F.S.)
5 mm/min
α = 2.5 / 73.5 (194 - 62)
= 258 μm/m °C


T M A
AIR
AS RECEIVED
ANNEALED AT 350°F
RED TRACE CHROMEL ALUMEL T C
5 mil/FS


G D T 15638
T M A
73.5 mil
10° C/MIN
ENVIRONMENT AIR
DELSEN TESTING LABORATORIES, INC.
1031 Flower Street
Glendale, California 91201
CONDITIONED
ANNEALED AT 200°F
.5 mil/F S
212°F
195°F
0.125 mil
RED TRACE CHROMEL ALUMEL T.C. (10 mV F S)
$\alpha = \frac{1.5}{73.5(107-24)}$
$= 246\ \mu in/in\ °C$
$\alpha = \frac{35}{73.5(1705-55)}$
$= 289\ \mu in/in\ °C$
5 min/inch


GD T1503
TMA
74 mil
10°
AIR
DEIBEN TESTING LABORATORIES INC
Glendale, California 91201
CONDITIONED
ANNEALLED AT 250°F
237°F
245°F
0.87 mil
RED TRACE CHROMEL ALUMEL T C (10mV F.S.)
5 mm/min
5 mil F S


G.D T 1565θ
T M A
76.5 mil
10°
AIR
DELSEN TESTING LABORATORIES, INC.
1031 Flower Street
Glendale, California 91201
CONDITIONED
ANNEALLED AT 300°F
5 mil / F.S
290°F
1.475
0.24 mil
RED TRACE: CHROMEL ALUMEL T.C (10mV F.S)
α = 0.75 / 76.5 (133 - 53.5)
= 123 μm/m °C
5 mm/inch
α = 2.5 / 76.5 (190.5 - 60)
= 250 μm/m °C


DELSEN TESTING LABORATORIES INC
Glendale, California 91201
CONDITIONED
ANNEALED AT 350°F
RED TRACE
CHROMEL ALUMEL T C (10 mV F S)
5 mm/inch
0.38 mil
0.9 mil

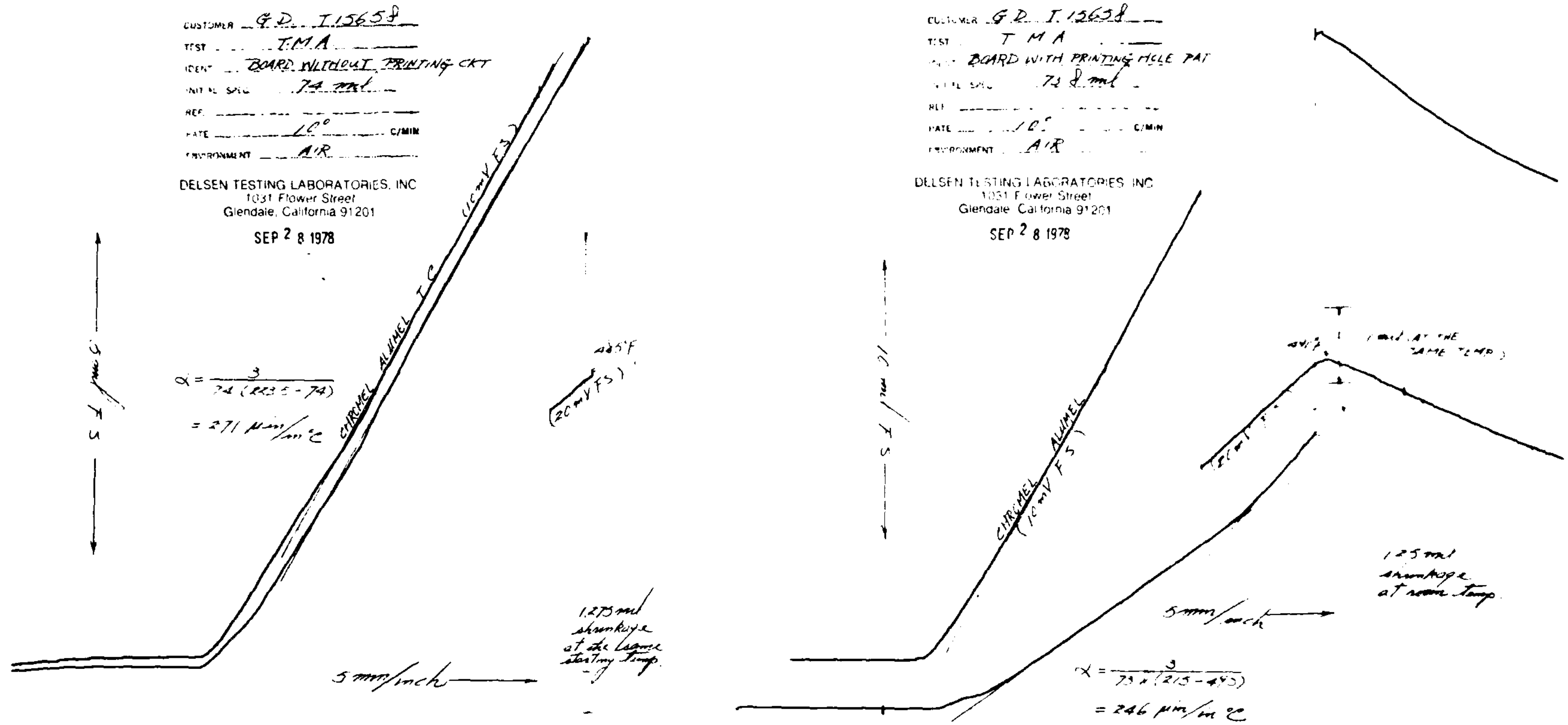


EXHIBIT 41. T.M.A. Curves for Rigid-Flex Cables Heated to 500^{o}F.

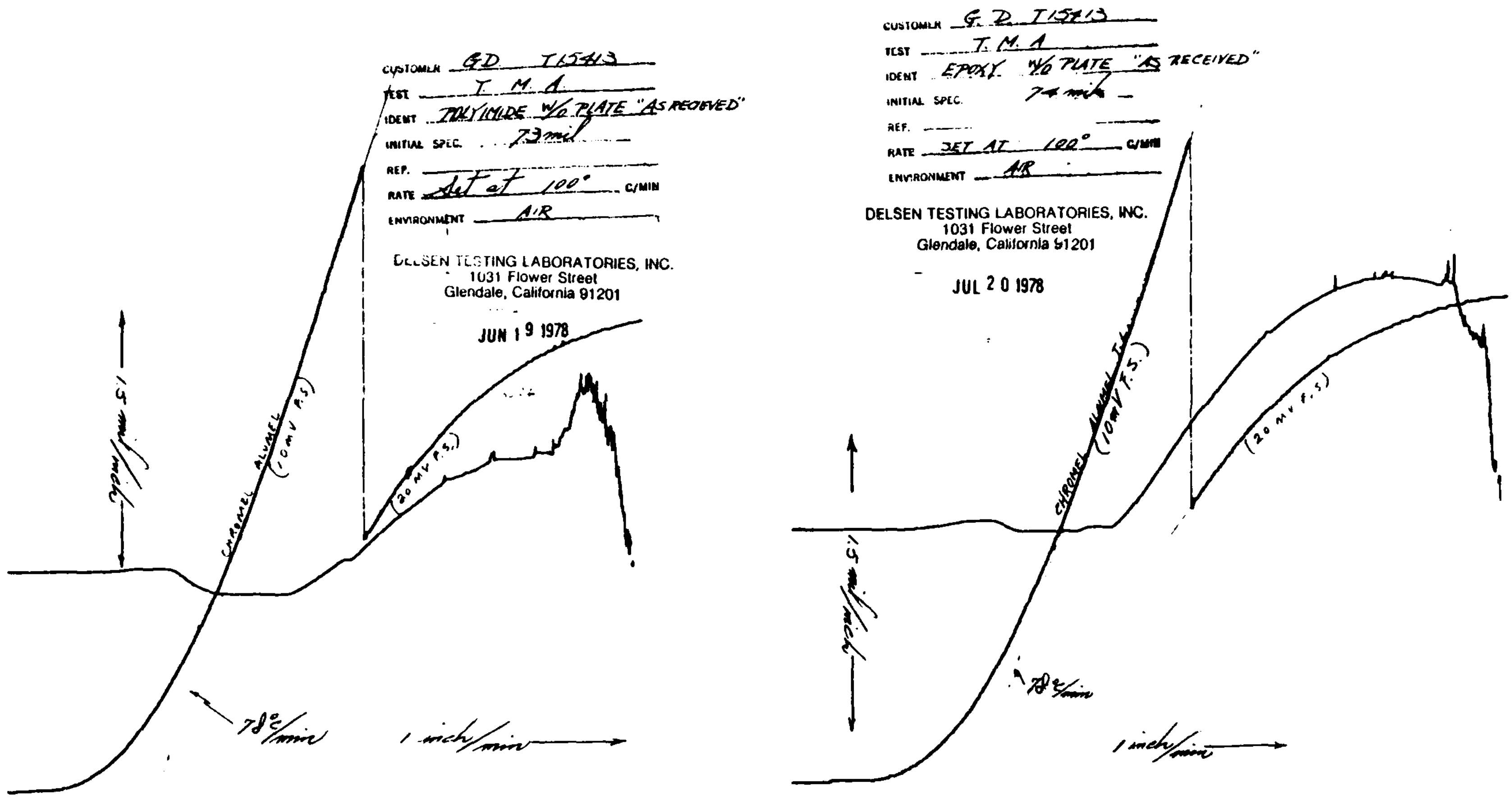


EXHIBIT 42. T.M.A. Curves for Rigid-Flex Cables Polyimide Versus Epoxy.

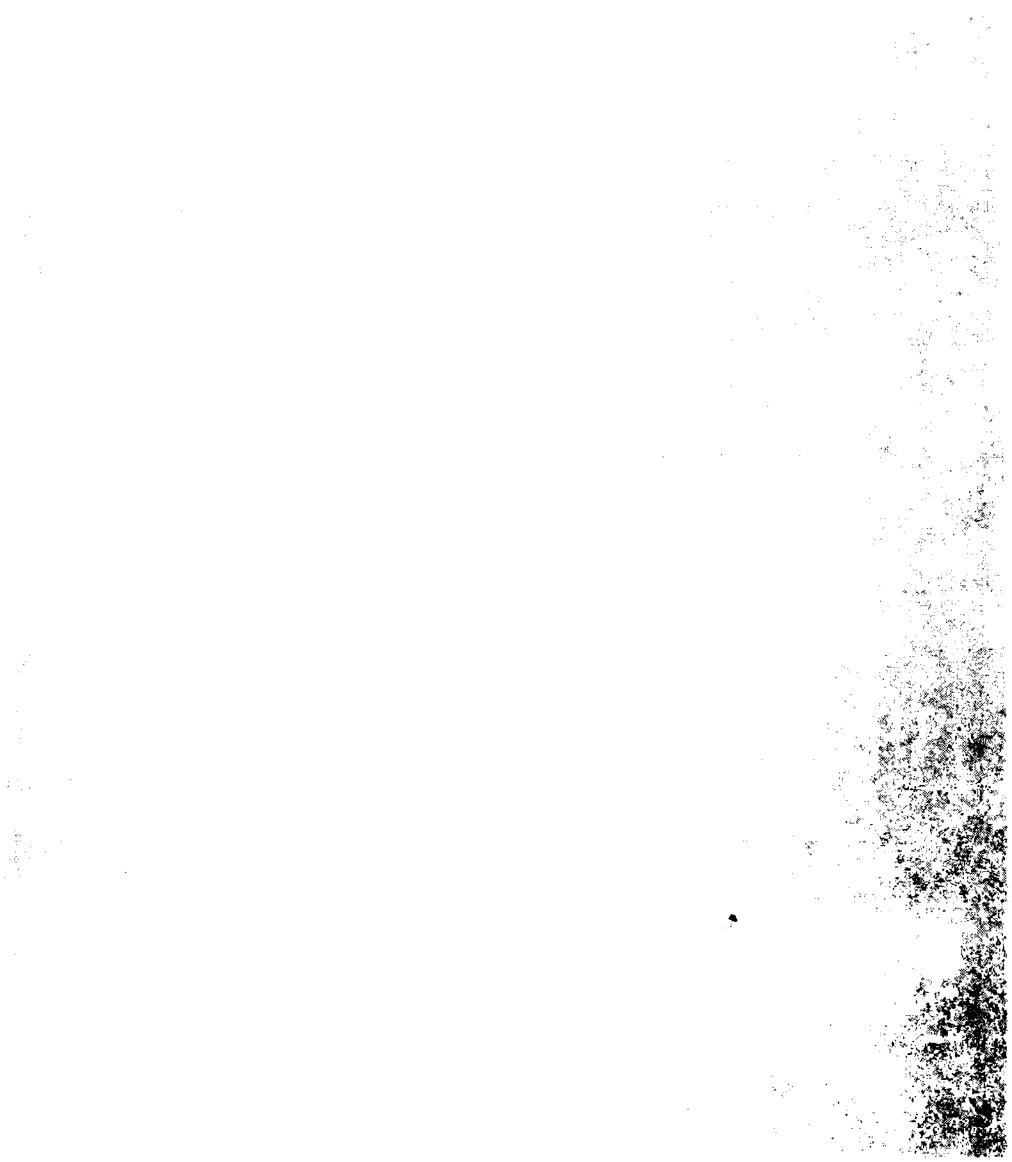


EXHIBIT 43. The cloudy area is where adhesive has lifted from the base Kapton of the copper clad Kapton.

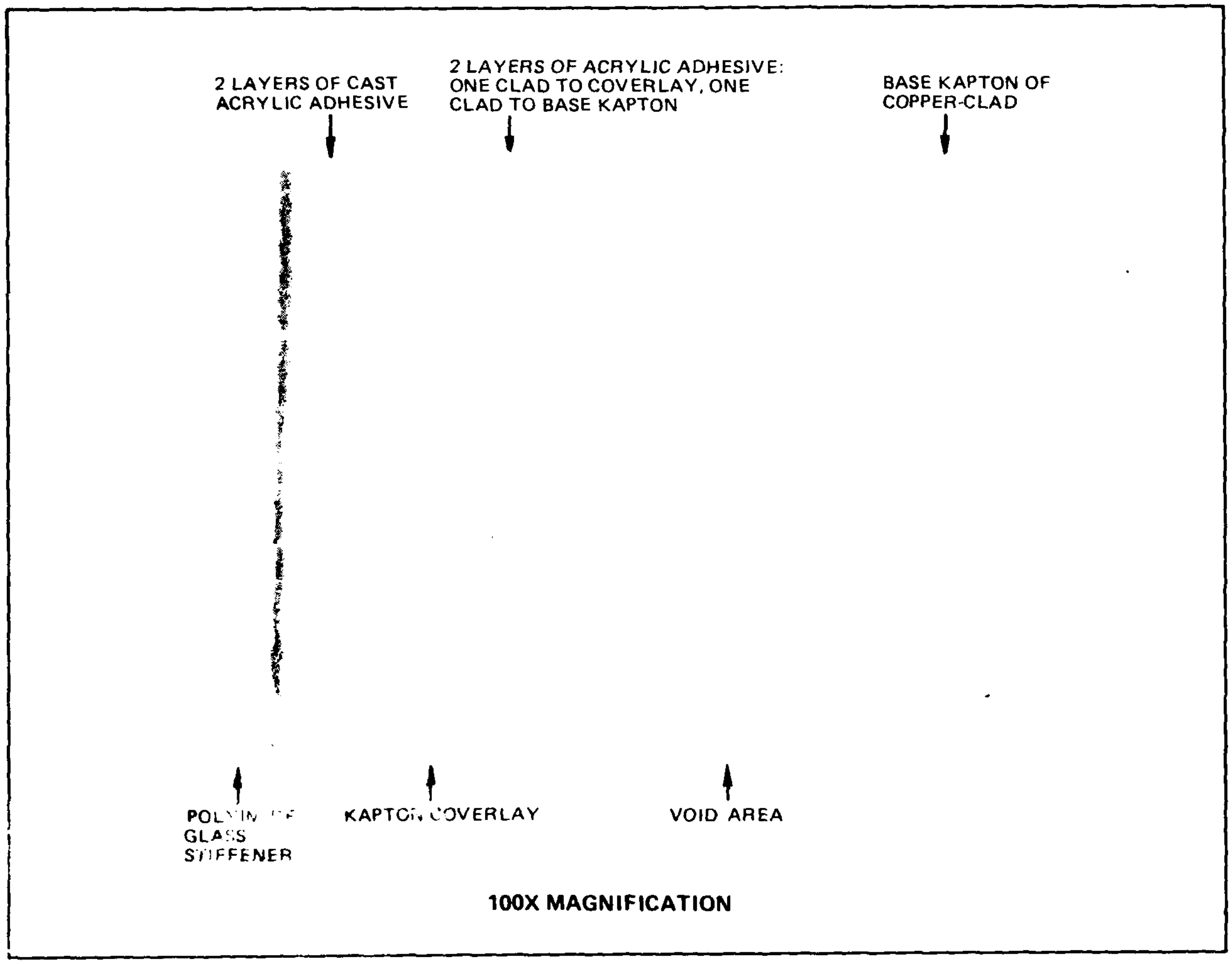


EXHIBIT 44. The area where the adhesive lifted from the base Kapton in Exhibit 43.

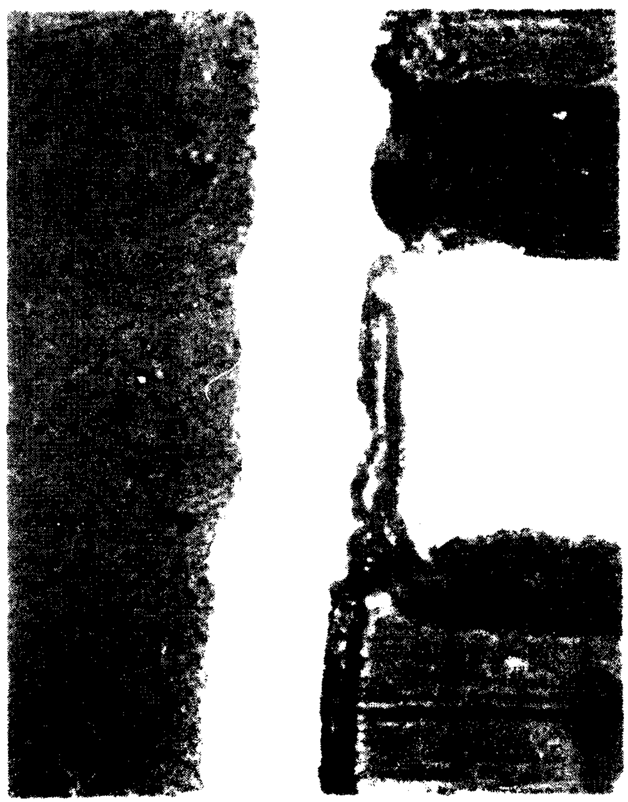


EXHIBIT 45. Cross section of cable 1 showing exuded or smeared organic material between the plated-through-hole and inner circuit layer.

EXHIBIT 46
FINAL TEST PROGRAM AND RESULTS

GENERAL DYNAMICS
Pomona Division
P O Box 2507 Pomona, California 91766 • 714-629-5111

Mfg. Tech. M-24-6-847

Date: 19 February 1979

INTERNAL CORRESPONDENCE

To: J. G. Park, M. D. Harbison, W. Olson, R. Williams

From: J. A. Reavill

Subject: Testing and Inspection of Rigid-Flex Printed Wiring Cables for N.O.S.C. Contract N00123-77-C-1192

The purpose of this memo is to make a formal request to the appropriate groups to perform the necessary tests on the hardware built for the Naval Oceans Systems Center (NOSC) under the subject contract. Charge numbers will be provided to the groups performing the tasks, namely the Quality Assurance Laboratories, Quality Assurance Electrical Testing (Q.A.E.T.), Inspection, and D/62 Operations, by the author of this memo, as required consistent with previous estimates.

GENERAL INFORMATION

Contract N00123-77-C-1192 is a Manufacturing Development program which deals with rigid-flex printed wiring cables. At the end of the program it is necessary that one complete rigid-flex cable composed of test patterns be tested and inspected to specific requirements. In addition, two 3217116 rigid-flex cables will be tested to the same requirements specified above, and others as shown in the "TEST REQUIREMENT AND DATA SHEETS" attached to this memo. It is expected that the one test pattern rigid-flex cable and one of the 3217116 cables will be destroyed in test.

The attached "TEST REQUIREMENT AND DATA SHEETS" specify the test specification, the test or inspection requirement, the test method, and the group which is requested to perform the task. In addition, a pictorial view of the test coupons or cable is provided to show the location of the specific test coupon relating to the specific test.

It should be noted at this time that the responsibility for overall acceptance of the tested hardware is upon the author of this memo and not with those groups performing the tests or inspections. The tests and inspections selected to be preformed were chosen by the author and are believed to be adequate to measure the results of the N.O.S.C. manufacturing development problem.

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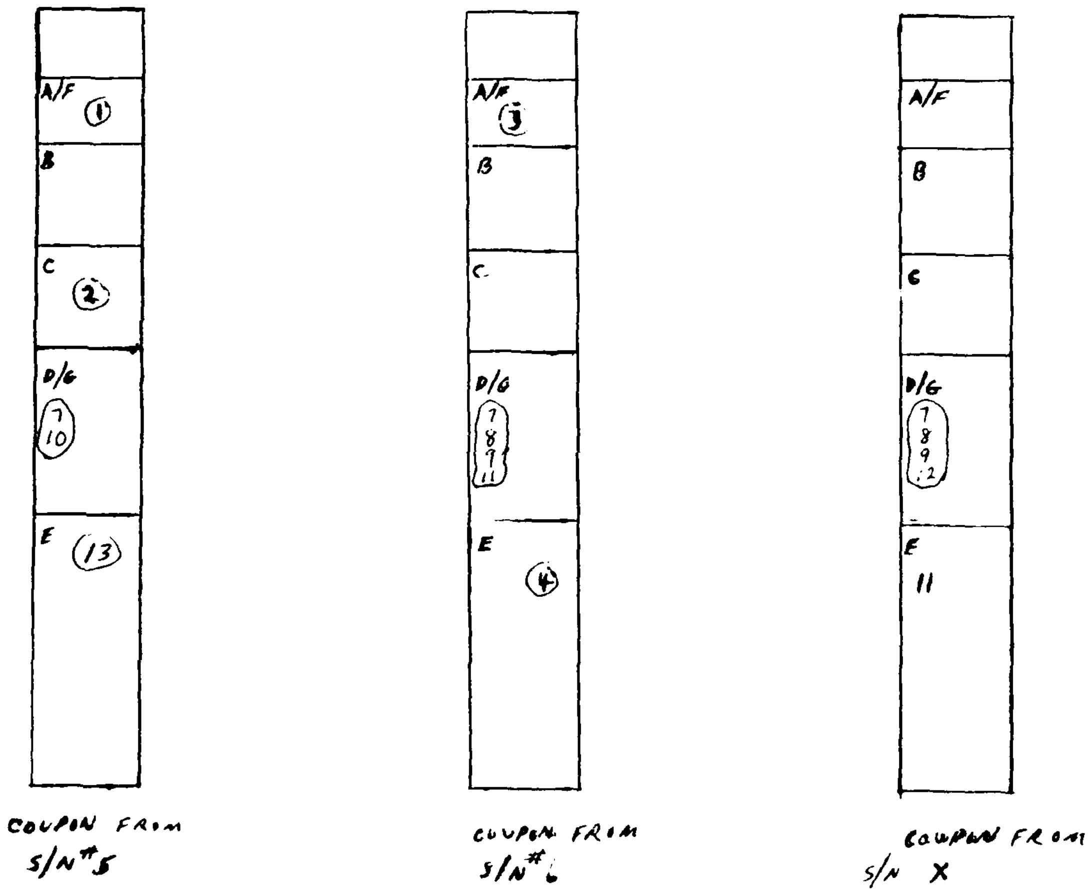
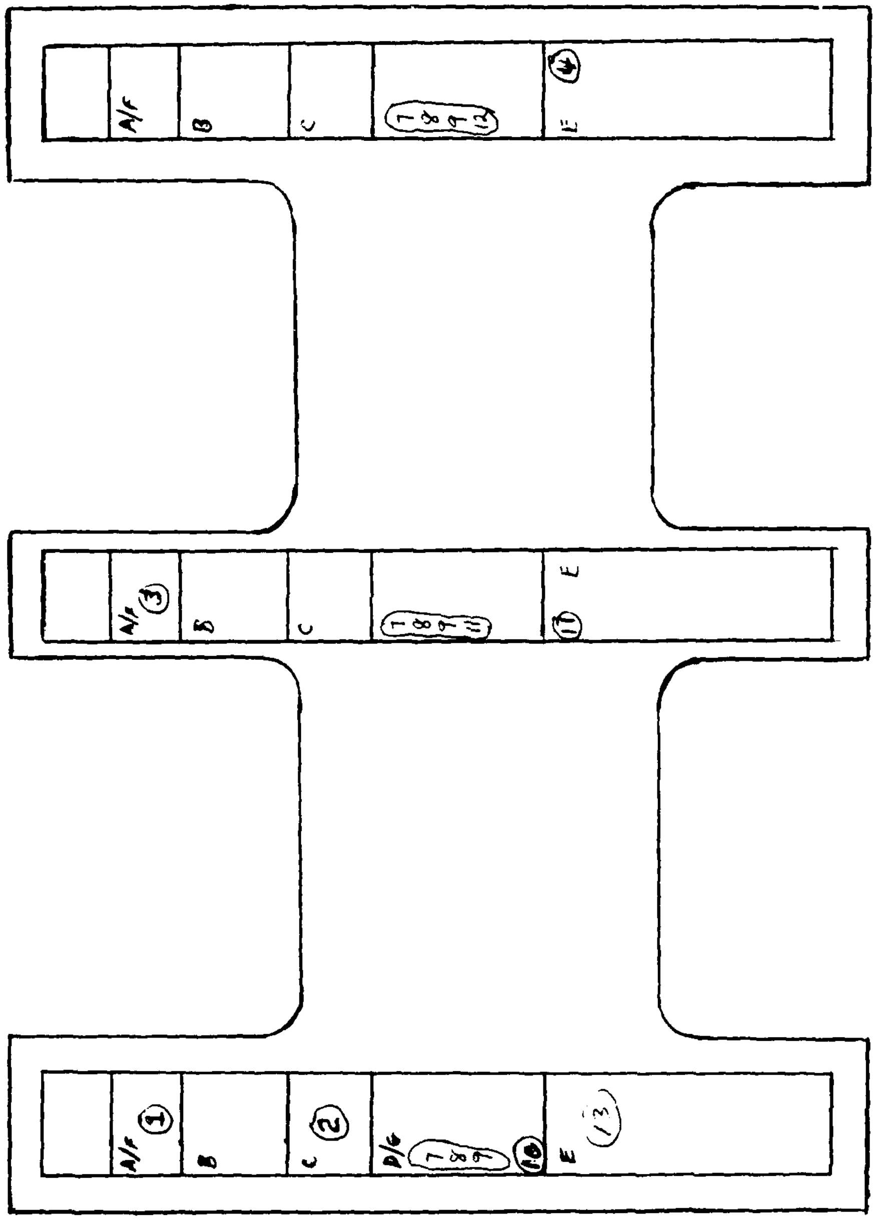
In general, the author of this memo would like to observe most of the inspections and tests performed for this program. The hardware will be provided as the program proceeds. The expected start date for testing is February 26, 1978

J A Reavill
J. A. Reavill
Advanced Manufacturing Technology



Coupons taken from 3 different P/N 3217116 flex-rigid cables. Serial number of the cable is shown below each. Each number represents a test coupon sample.



TEST PATTERN RIGID-FLEX CABLE

Shows test coupon number and area of panel from which it comes.

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TEST REQUIREMENT AND DATA SHEET

TESTS TO BE PERFORMED BY

D/62 OPERATIONS

Supervisor: R. Williams

Part Number 3217116

Test Specification: GD/P 3626

Equipment: Automatic Wiring System Analyzer, Ditmco Space VII

Test Description: DrawingX1A-000

Continuity: Current 1.0 amp
Resistance limit 1.00 x 1Ω
Dwell time adjust fully ccw

Insulation: Test voltage 500
Resistance limit 2.00 x 10 meg

Conforms: ______________________

Does not conform: ________________

REMARKS ______________________________________
____
____
____

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TEST REQUIREMENT AND DATA SHEET

TESTS TO BE PERFORMED BY

QUALITY ASSURANCE, INSPECTION, D/62 (CONTINUED)

Supervisor: W. Olson

Inspection Specification: Mil-P-55640A, Visual/Dimensional Requirements - Table III

Inspection Characteristics	Requirement	Test Pattern Rigid-Flex		P/N 3217116 Rigid-Flex	
		PASS	FAIL	PASS	FAIL
Delamination or blisters	None allowed				
Immersion tin plating	Complete pad coverage				
Nodules	Cannot close holes beyond min. Dia.				
Contamination	None allowed				
Lifted pads or circuits	None allowed				
Plating on conductors	Smooth, with no slivers or whiskers				
Adhesive on pads	None allowed				

REMARKS: ____________________

GENERAL DYNAMICS
Pomona Division

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TEST REQUIREMENT AND DATA SHEET

TESTS TO BE PERFORMED BY

QUALITY ASSURANCE, INSPECTION, D/62

Supervisor: W. Olson

Inspection Specification: Mil-P-55640A, Visual/Dimensional Requirements - Table III

Inspection Characteristics	Requirement	Test Pattern Rigid-Flex		P/N 3217116 Rigid-Flex	
		PASS	FAIL	PASS	FAIL
Machineability	No splits, cracks, frayed edges, delamination or other degradation				
Repair	None allowed				
Marking	P/N on 3217116 Rigid Flex only, S/N in ink on both				
Dimensional Requirements Verify X-ray for inner layer registration	P/N 3217116 B.P Rqt's No hole break-out				
External-pad surrounding termination holes	.005" *minimum*				
Minimum clearance between conductors	.009"				
Minimum clearance between edge & terminal pad	.020"				
Minimum clearance from conductor to edge of clearance hole	.015"				
Warp and twist	Para 3.9				
After thermal shock	" "				
After moisture resistance	" "				
Workmanship					
Verify presence of all circuit pads					
Physical damage, cracks tears, cuts, deep scratches, sharp notches or burrs	None allowed				

Continued on Page 2

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19 February 1979

TEST REQUIREMENT AND DATA SHEET

TESTS TO BE PERFORMED BY

QUALITY ASSURANCE ELECTRICAL TESTING Q.A.E.T.

Supervisor: S. Harbison

Test Specification: Mil-P-55640A, Table III

Test Description	Test Requirement		Coupon #	Test Pattern Rigid-Flex		P/N 3217116 Rigid-Flex	
				PASS	FAIL	PASS	FAIL
Initial							
Insulation Resistance	Para 3.16	Para 4.7.11	5				
Dielectric Withstanding	Para 3.17	Para 4.7.12.1	6				
Circuit Continuity	Para 3.13	Para 4.7.8	7				
Interconnection Resistance	Para 3.18	Para 4.7.13	9				
After Thermal Shock Conditioning	Para 3.12	Para 4.7.7	12				
Circuit Continuity		Para 3.13	12				
After Moisture Resistance Conditioning	Para 3.15	Para 4.7.10	11				
Insulation Resistance	Para 3.16	Para 4.7.11	11E				
Dielectric withstanding	Para 3.17	Para 4.7.12	11E				
Circuit Continuity	Para 3.13	Para 4.7.8	11D/G				
Verify 500 Meg Ohms During high temperature of cycle	Para 3.15						

REMARKS: ____________________

GENERAL DYNAMICS
Pomona Division

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TEST REQUIREMENT AND DATA SHEET

TESTS TO BE PERFORMED BY

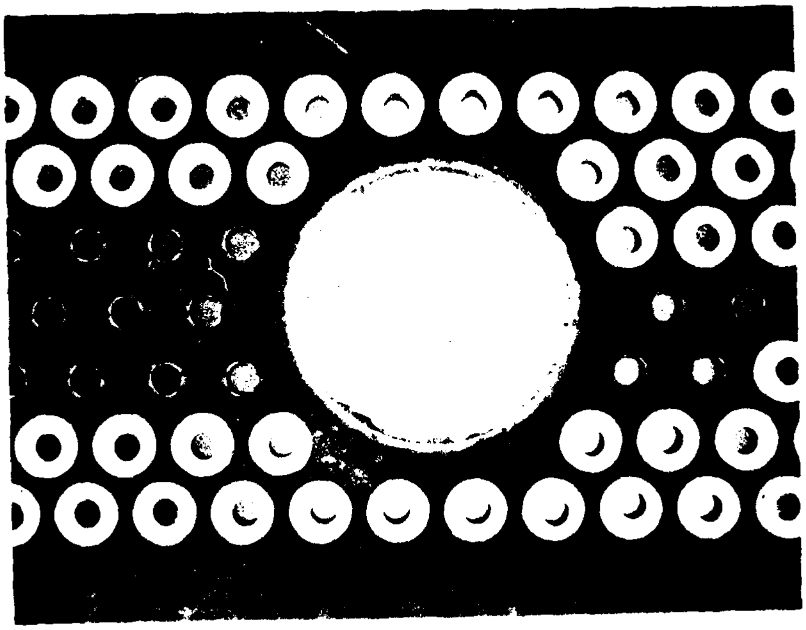
THE QUALITY ASSURANCE LABORATORIES

Supervisor: J. G. Park

Test Specification: Mil-P-55640A, Table III

Test Description	Test Requirement	Test Procedure	Coupon Number	Test Pattern Rigid-Flex		P/N 3217116 Rigid-Flex	
				PASS	FAIL	PASS	FAIL
Plating Copper Tin, electroless	Table 1 .001 Min. Full coverage	Para 4.7.1 Cross Secion	1				
Plated through hole	Para 3.5-3.5.2	4.7.1.1	1				
Layer to Layer registration	Para 3.6.1.3						
Dielectric Material	Para 3.6.2		1				
Plating adhesion	Para 4.7.2		2				
Bond strength (Terminal Pull)	Para 3.8	Para 4.7.3	3				
Hot Oil Resistance	Para 3.10	Para 4.7.5	4				
Current Carrying Capacity	Para 3.14	Para 4.7.9	8				
Thermal Stress	Para 3.19	Para 4.7.14	10				
Solderability	MIS 23456A		13				
Cross Section of soldered terminals	No inner layer separation or other degradation visible	Magnification 200x+	P/N 321716 Destruct Cable				

REMARKS: ____________________



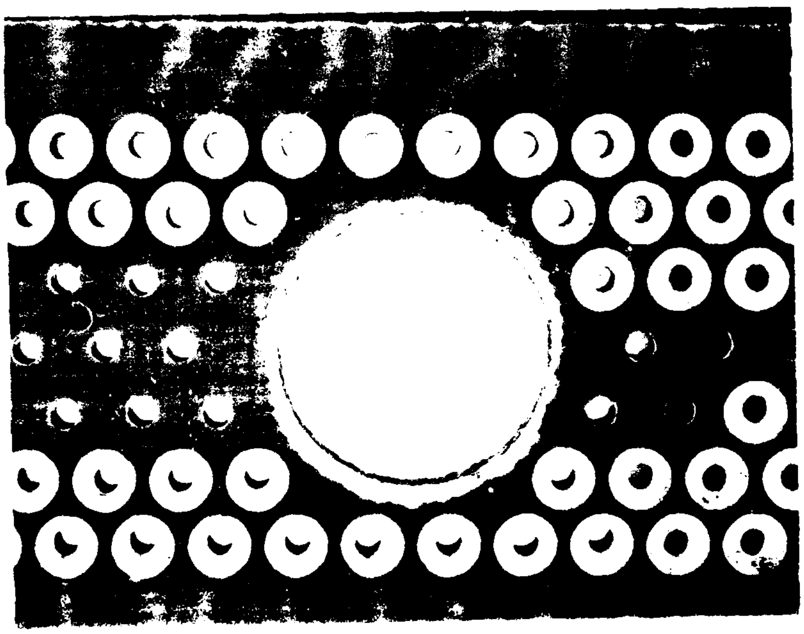


EXHIBIT 47. Shows the haloed area of the connector fastener hole (diameter 0.300 in.).

Note: Only the exit side of the hole was affected.

EXHIBIT 48

COST ANALYSIS REPORT

Purpose: This report compares the manufacturing costs for producing rigid-flex cables using both present state of the art techniques and newly developed techniques.

Scope: The intent of this analysis is not to provide all detail costs necessary for setting-up a printed wiring fabrication facility. It is assumed that any manufacturer capable of producing rigid-flex cables will have basic work areas, equipment, tools and personnel which will perform to the minimum processing requirements specified.

It is the intent of this analysis to show the cost saving which can be achieved as a result of the NOSC development program (N00123-77-C-1192). The major technology innovations are a substitution of polyimide glass laminate for epoxy glass laminate as cable outer stiffeners and the accompanying process improvements.

Cost Analysis:

Current Fabrication Costs of a P/N 3217116 Rigid-Flex Cable.

The current cost of manufacturing a standard missile (SM-2) guidance computer rigid-flex cable (P/N 3217116) is $510 at General Dynamics/Pomona Division. The relatively high cost is derived from the 60% average yield obtained at present.

Material Cost Differential is $621

Epoxy Glass Laminate - 2.50/Ft^2 (TLGE 010C 1/0B1 per Mil-P-55617B)

Polyimide Glass Laminate - (TLGI 010C 1/0 B1 per Mil-P-55617B) 664/Ft^2

Flexible material (copper clad, adhesive film and coverlayer) cost is equal for units produced using either new or present fabrication techniques.

Each cable requires 1.5 Ft^2 per unit therefore the total cost differential is 6.21 in comparing polyimide and epoxy laminates.

Tooling Cost Differential is 0

The present vacuum laminating process requires special lamination fixtures which cost $600 each. In addition a vacuum pump costing approximately $1500 is required. This cost occurs only once during the life of the contract and will offset the $.50 per unit added cost of teflon press pads which are required in the improved lamination process.

Labor Cost Differential is 0

Yield Improvement is Projected to be 25%

Current average yield is approximately 60%

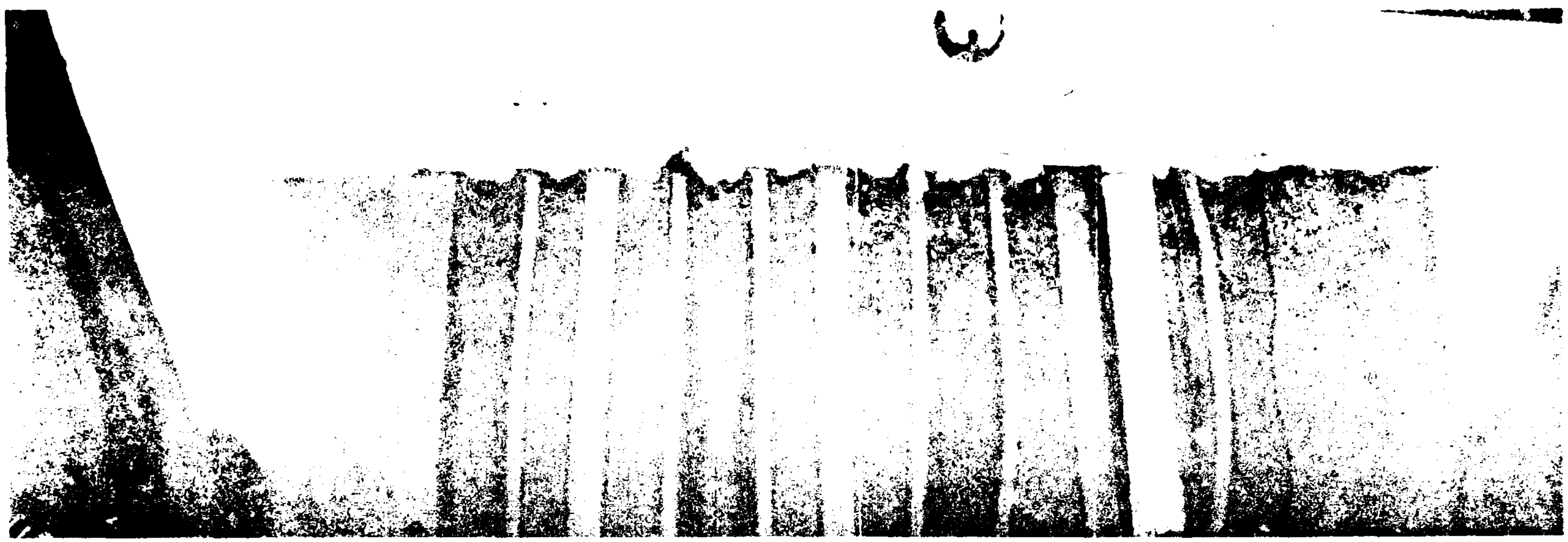
Expected yield will be 85%

Individual Manufacturing Processes Improved

Lamination	15%
Drilling	5%
Plasma drill smear removal	3%
Plating	2%
Total	25%

Resultant Cost Saving

Yield improvement cuts from $510/unit to $361/unit.



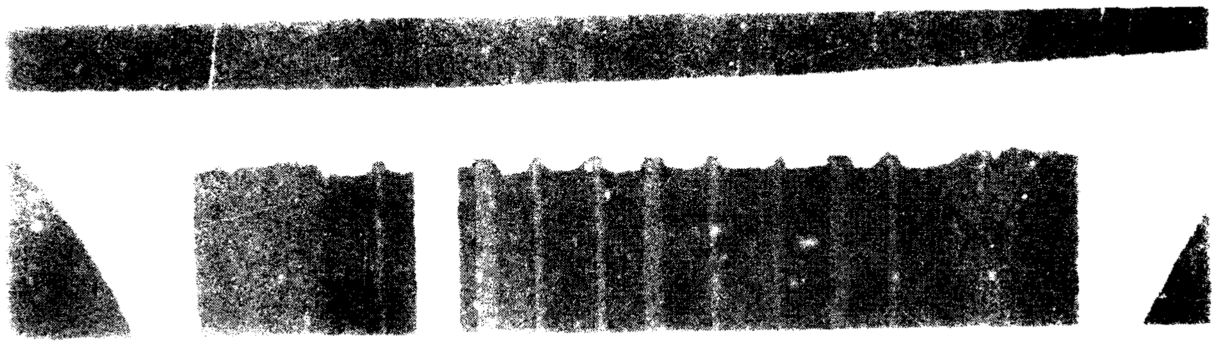
NOTE:

TERMINAL PIN HAS BEEN SOLDERED INTO PLATED–THROUGH HOLE. THERMAL EXPANSION HAS CAUSED TILTING OF CIRCUITRY RESULTING IN INNER LAYER SEPARATION.

EXHIBIT 49. Rigid-Flex Printed Wiring Cable Constructed With Epoxy Glass Stiffeners.

EXHIBIT 50. Rigid-Flex Printed Wiring Cable Constructed With Polyimide Glass Stiffeners.

RIGID-FLEX PRINTED WIRING CABLE CONSTRUCTED WITH POLYIMIDE GLASS STIFFENERS

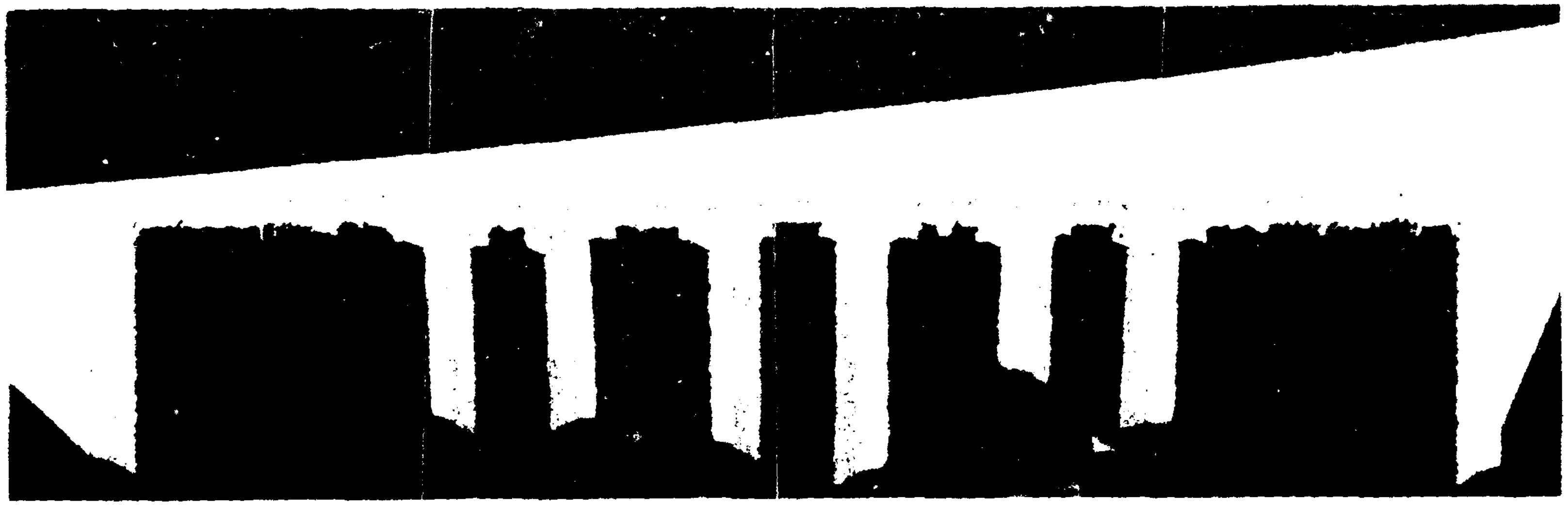


NOTE:

TERMINAL PIN HAS BEEN SOLDERED INTO PLATED–THROUGH–HOLE. NO THERMAL EXPANSION EFFECTS ARE EVIDENT

F219877 759

RIGID-FLEX PRINTED WIRING CABLE CONSTRUCTED WITH POLYIMIDE GLASS LAMINATE



NOTE:

TERMINAL PIN HAS BEEN SOLDERED INTO PLATED–THROUGH HOLE. NO THERMAL EXPANSION EFFECTS ARE EVIDENT

EXHIBIT 51

MATERIAL SPECIFICATIONS
FOR
RIGID-FLEX PRINTED WIRING CABLES

MATERIAL SPECIFICATION
FOR
PLASTIC SHEET, THIN LAMINATE, METAL CLAD
(FOR RIGID-FLEX PRINTED WIRING CABLES)

1. SCOPE

1.1 Scope. This specification covers the requirements and test procedures for fully cured, metal clad, thin laminated plastic sheets which are to be used as stiffeners in rigid-flex printed wiring cables. This document is limited to laminates with a maximum core thickness of 0.031 inch and with polyimide glass construction. All references to MIL-P-55617B shown in this specification apply to the subject material except for those additions or deletions indicated.

1.2 Classification. Reference Paragraphs 1.2 - 1.2.1.7 of MIL-P-55617B. The primary thin clad designation is TL GI 0100 C 1/1 A 1.

2. APPLICABLE DOCUMENTS. Reference Paragraphs 2.0 - 2.2 of MIL-P-55617B.

3. REQUIREMENTS

3.1 General Material Requirements. Reference Paragraphs 3.0 - 3.9 including Table III of MIL-P-55617B with the following additions and changes:

- Add to Paragraph 3.3.5 - The color of the laminate shall be uniform across the entire panel. Dark borders are not acceptable.
- Add Paragraph 3.3.6.2 - Copper thickness shall be 0.0014 inch $\pm$ 0.0002 inch as measured from the top surface of the foil to the valley of the surface toothing on the bottom side. The measurement shall be made optically at 350 X min. from an edgewise cross section.
- Add Paragraph 3.3.6.3 - The bonded copper foil surface shall have a layer (equal or equivalent to brass) to promote adhesion of the polyimide resin to the copper metal and inhibit chemical attack of the bond.
- Add to Paragraph 3.9 - In addition, the laminate shall exhibit a relative flatness of 10% in the un-restrained condition. Edge curl or other tension in the laminate which causes greater than a 10% deviation in flatness is unacceptable (as measured in Paragraph 4.2.8 or M-24-6-875).
- Change Table III. Dimensional stability requirement "After Temperature Cycling" from 0.0003 inch to 0.0005 inch per inch.

3.2 Qualification Inspection. Reference Paragraph 4.5 - 4.55 and 6.4 of MIL-P-55617B.

3.3 Differentiating Requirements. The entire differentiating requirements are defined by the designation TL GI 0100 C 1/1 A 1 as referred to in Paragraphs 1.2 - 1.2.1.7 of MIL-P-55617B.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection

4.2 Special tests and examinations - Reference Paragraphs 4.0 - 4.6.3 of MIL-P-55617B

4.3 Quality conformance inspection

4.4 Test methods - Reference Paragraphs 4.7 - 4.7.13 of MIL-P-55617B.

- Delete Paragraph 4.7.1.1 Heading. ETCHING PROCESS AND ETCHANT REMOVAL ...
- Add Paragraph 4.7.1.1 - Heading. ETCHING PROCESS AND ETCHANT REMOVAL (See 3.5.2). This process shall be performed only as specified in each test method provided below. The specific method chosen shall be that which uses the same chemical etchant which is used to produce the subject rigid-flex cables.
- Add to Paragrah 4.7.1.1 Method C.
  1. Remove foil from specimen using a water solution containing 7% by weight chromic acid and 20% by weight sulfuric acid, specific gravity 1.836 (66°B'e). The temperature shall be 120° $\pm$ 15°F and vigorous solution agitation must be provided for the entire minimum time for metal removal.
  2. Rinse specimens thoroughly in running tap water.
  3. Immerse specimens in a 10-15 percent (weight) solution of sodium metabisulfite in water at 15.6° to 32.2°C (60°-90°F) for 10 minutes while providing gentle specimen or solution agitation.
  4. Rinse specimens thoroughly in running tap water.
  5. Immerse specimens in a 10% (VOL), solution of Hydrochloric acid, specific gravity 1.192, and water at 15.6° to 32.2°C (60°-90°F) for 1 minute while providing gentle specimen or solution agitation.
  6. Rinse specimens thoroughly in running tap water.
  7. Immerse specimens in Methyl Ethyl Ketone until resist is removed.
  8. Gently scrub specimen with a plastic-bristled brush under running tap water and rinse for 10 minutes.
  9. Rinse the specimen in distilled water.
  10. Dry specimens for 1 hour in an oven at 80° $\pm$ 3°C (176° $\pm$ 5.4°F). Handle the specimens using edge contact only and use rubber or polyethylene gloves if specimens are to be electrically tested.
- Add to Paragraph 4.7.1.1 Method D.
  1. Remove foil from specimen using a water solution containing a 30-35 B'e solution of cupric chloride and hydrochloric acid. The temperature shall be 130° $\pm$ 5°F and vigorous solution agitation must be provided for the entire minimum time for metal removal.
  2. Rinse specimens thoroughly in running tap water.

3. Immerse specimens in a water solution containing 5% (weight) ammonium persulfate and 0.5% (VOL) sulfuric acid, specific gravity 1.836 (66°B'e) at 15.6°C (60° - 90°F) for 3 minutes.
4. Rinse specimens thoroughly in running tap water.
5. Immerse specimens in Methyl Ethyl Ketone until resist is removed.
6. Rinse specimens thoroughly in running tap water.
7. Gentle scrub specimens with a plastic-bristled brush under running tap water and rinse for 10 minutes.
8. Rinse the specimen in distilled water.
9. Dry specimens for 1 hour in an oven at 80° ± 3°C (176° ± 5.4°F). Handle the specimens using edge contact only and use rubber or polyethylene gloves if specimens are to be electrically tested.

5. PREPARATION FOR DELIVERY. Reference Paragraphs 5.1 - 5.4 of MIL-P-55617B.

6. NOTES. Reference Paragraphs 6.1 - 6.8 of MIL-P-55617B.

GENERAL DYNAMICS
Pomona Division

TRANSMITTAL AND SIGNATURE SHEET

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ISSUE AND APPROVAL RECORD

ISSUE	DESCRIPTION	DATE
Original	This specification establishes the material requirements and acceptance tests for copper clad polyimide insulating sheets. APPROVED ____________________ U.S. Army Missile Research and Development Command	

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MISSILE RESEARCH AND DEVELOPMENT

COMMAND SPECIFICATION

MATERIAL SPECIFICATION FOR

INSULATING SHEET, POLYIMIDE, COPPER CLAD

1. SCOPE AND CLASSIFICATION

1.1 Scope. This specification specifies the material requirements and acceptance for copper clad polyimide insulating sheet (see 6.1), hereinafter referred to as the material.

2. APPLICABLE DOCUMENTS

2.1 Government documents. The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

SPECIFICATIONS

Military

MIL-P-13949	Plastic Sheet, Laminated, Metal-Clad (for Printed Wiring), General Specification for
MIL-C-45662	Calibration System Requirements
MIL-P-46112	Plastic Sheet and Strip, Polyimide

U.S. Army Missile Research and Development Command

MIS-23661	Material Specification for Film, Adhesive

STANDARDS

Military

MIL-STD-129	Marking for Shipment and Storage

MIL-STD-130	Identification and Marking of U.S. Military Property
MIL-STD-202	Test Methods for Electronic and Electrical Component Parts

(Copies of specifications and standards required by suppliers in connection with specified procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Non-Government documents. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated the issue in effect on the date of invitation for bids or request for proposal shall apply.

OTHER PUBLICATIONS

Uniform Classification Committee

Uniform Freight Classification	Ratings, Rules and Regulations

(Application for copies should be addressed to the Uniform Classification Committee, Room 1106, 222 South Riverside Plaza, Chicago, Illinois 60606).

American Society for Testing and Materials (ASTM)

ASTM D149	Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies
ASTM D150	A-C Loss Characteristics and Dielectric Constant (Permittivity) of Solid Electrical Insulating Materials
ASTM D1000	Pressure-Sensitive Adhesive Coated Tapes Used for Electrical Insulation

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103).

Institute of Printed Circuits (IPC)

IPC-CF-150	Copper Foil for Printed Wiring Applications
IPC-TM-650	Test Methods Manual

(Application for copies should be addressed to the Institute of Printed Circuits, 1717 Howard Street, Evanston, Illinois 60202.)

3. REQUIREMENTS

3.1 General material requirements. The material shall be copper clad polyimide, formulated and processed to meet the requirements of this specification.

3.1.1 Quality. The material shall be a sheet fabricated by bonding the materials of 3.1.2 with an adhesive that yields a product that will meet the requirements specified herein.

3.1.2 Formulation. The material shall be comprised of polyimide meeting the requirements of MIL-P-46112, type I, and rolled copper meeting the requirements of IPC-CF-150, rolled, annealed. The copper may be treated to improve bondability. The copper shall be bonded to the polyimide using adhesive complying with MIS-23661.

3.1.3 Product characteristics.

3.1.3.1 Pits and dents. The copper foil shall comply with the pits and dents requirements specified in MIL-P-13949, grade B, except that the longest dimension for pits shall be 0.005 inch.

3.1.3.2 Wrinkles. The material shall exhibit no wrinkles on the copper clad surface.

3.1.3.3 Thickness. The thickness of the material shall be as specified in table I.

3.1.4 Chemical, electrical and mechanical properties.

3.1.4.1 Dielectric constant. The dielectric constant of the material with the copper removed shall be 4.0, maximum, at 100 kilohertz (kHz) and 25 degrees Centigrade (77 degrees Fahrenheit).

3.1.4.2 Dissipation factor. The dissipation factor of the material with the copper removed shall be 0.1, maximum, at 100 kHz and plus 25 degrees Centrigrade (plus 77 degrees Fahrenheit).

3.1.4.3 Dielectric strength. The dielectric strength of the material with the copper removed shall be 2000 volts, minimum, per mil of thickness.

Table I. Material thickness

Dash no.	Copper thickness side 1	Adhesive	Dielectric thickness	Adhesive	Copper thickness side 2	Total thickness (inch) (±12.5 percent)
-001	1 oz.	Yes	2 mil	No	None	0.004
-002	1 oz.	Yes	2 mil	Yes	1 oz.	0.007
-003	2 oz.	Yes	2 mil	No	None	0.006
-004	2 oz.	Yes	2 mil	Yes	2 oz.	0.010
-005	3 oz.	Yes	2 mil	No	None	0.007
-006	3 oz.	Yes	2 mil	Yes	3 oz.	0.012
-007	2 oz.	Yes	3 mil	No	None	0.007
-008	2 oz.	Yes	3 mil	Yes	2 oz.	0.011
-009	3 oz.	Yes	3 mil	No	None	0.008
-010	3 oz.	Yes	3 mil	Yes	3 oz.	0.013

3.1.4.4 Volume resistivity. The volume resistivity of the material with the copper removed shall be 1.0 times 10^{12} ohms per centimeter, minimum.

3.1.4.5 Surface resistivity. The surface resistivity of the material with the copper removed shall be 1.0 times 10^{12} ohms per centimeter, minimum.

3.1.4.6 Insulation resistance. The insulation resistance of the material shall be 100 megohms, minimum.

3.1.4.7 Elongation. Copper foil weighing 1.0 ounce per square foot shall have a minimum of 10 percent elongation. Copper foil weighing 2 ounces per square foot and 3 ounces per square foot shall have a minimum of 20 percent elongation.

3.1.4.8 Peel strength after process exposure. The material shall have a minimum peel strength of 7 pounds per inch of width and shall show no visible defects, after exposure to the following process:

(a) Application of suitable resist image and etch in ferric chloride etchant (P.A. Hunt Hi-Speed circuit etch, or equivalent) at plus 54 (plus or minus 6) degrees Centigrade [plus 130(plus or minus 10) degrees Fahrenheit].

(b) Exposure to Riston 1100X (Du Pont) photo resist stripper at plus 74 (plus or minus 6) degrees Centigrade [plus 165 (plus or minus 10) degrees Fahrenheit].

(c) Presolder bake at plus 135 (plus or minus 3) degrees Centigrade [plus 275 (plus or minus 10) degrees Fahrenheit] in air, or at plus 77 (plus or minus 3) degrees Centigrade [plus 170 (plus or minus 5) degrees Fahrenheit] and minimum vacuum of 635 millimeters (25 inches) of mercury.

(d) Solder float in plus 288 (plus or minus 3)-degree Centigrade [plus 550 (plus or minus 5) degree Fahrenheit]-solder for 5 seconds, minimum.

3.1.4.9 Flexural fatigue. The material, with the following copper cladding, shall withstand the specified number of flexural cycles without loss of electrical continuity:

	Copper cladding	Number of cycles
(a)	1.0 ounce per square foot	75
(b)	2 ounces per square foot	50
(c)	3 ounces per square foot	37

3.1.5 Environmental conditions.

3.1.5.1 Moisture absorption. The moisture absorption of the material with the copper removed shall be 4 percent, maximum, when immersed for at least 24 hours in water at a temperature of plus 23 (plus or minus 1.0) degrees Centigrade [plus 73 (plus or minus 2) degrees Fahrenheit].

3.1.5.2 Dimensional stability after thermal exposure. The material shall exhibit 0.002 inch per inch, maximum, dimensional change due to total metal removed after an exposure to plus 150 (plus or minus 2) degrees Centigrade [plus 302 (plus or minus 4) degrees Fahrenheit] for 30 (plus or minus 2) minutes.

3.1.5.3 Solder dip resistance. The material shall show no evidence of delamination or blistering after being immersed for 10 seconds, minimum, in plus 260 (plus or minus 5) degrees Centigrade [plus 500 (plus or minus 9) degrees Fahrenheit] solder.

3.1.5.4 Thermal shock resistance. The material shall show no deterioration, damage, or corrosion, and the continuity resistance shall not vary more than 50 percent and shall not exceed 1.0 ohm at any time after exposure to five cycles of the following temperatures and times: 30 minutes, minimum, at minus 65 (plus 0, minus 5) degrees Centigrade [minus 85 (plus 0, minus 9) degrees Fahrenheit] followed by 30 minutes, minimum, at plus 177 (plus 3, minus 0) degrees Centigrade [plus 350 (plus 5, minus 0) degrees Fahrenheit] with transfers between temperatures accomplished within 5 minutes.

3.1.5.5 Fungus resistance. The material shall exhibit resistance to fungus growth during exposure to fungus at a temperature of plus 30 degrees Centigrade (plus 86 degrees Fahrenheit) at 95 percent relative humidity for 28 days.

3.1.6 Identification and marking. The material shall be marked for identification in accordance with MIL-STD-130 by stamping or other permanent methods. Markings, paper labels or decalcomanias which will deteriorate due to environmental or other conditions specified herein shall not be used. Identification shall include the following:

(a) Specification number

(b) Supplier's designation.

3.1.7 Workmanship. All material shall be finished in a thoroughly workmanlike manner, clean, uniform in appearance, free from wrinkles, blisters, and pinholes, and free from areas where the metal is not firmly bonded to the substrate. After the foil has been removed by etching, there shall be no visible evidence of metal, metal oxide, or other metallic particles (or foreign particles), either on the surface or embedded in the substrate. All dielectric surfaces, both those which are normally unclad and those from which the metal foil has been removed, shall be uniform in appearance, showing no excessive mottling resulting from nonuniform coating. No scorched areas shall be apparent.

3.2 Qualification.

3.2.1 Pilot lot. Unless otherwise specified in the contract or purchase order (see 6.2), a pilot lot shall be manufactured using the same methods and procedures proposed for production materials. Further production of the materials prior to approval of the pilot lot shall be at the supplier's risk. No design change shall be made after acceptance of the pilot lot without the prior approval of the procuring activity. Unless otherwise specified in the contract or purchase order, the following shall require performance of a pilot lot inspection (see 6.2):

(a) Original procurement

(b) Design change

(c) Break in production of greater than 6 months

(d) Relocation of supplier facilities

3.2.2 Periodic conformance. Unless otherwise specified in the contract or purchase order (see 6.2), quantities of sheets shall be inspected after 6 months from the successful completion of pilot lot inspection, and if over 12 months have elapsed since the previous periodic conformance inspection was successfully completed for compliance with the requirements specified herein and subjected to the inspections as specified in 4.1.2.2.

3.3 Precedence. When the requirements of the contract, this specification, or applicable subsidiary specifications, standards, drawings, or other publications are in conflict, the following precedence shall apply:

(a) Contract. The contract shall have precedence over any other requirements.

(b) This specification. *This specification shall have precedence* over all referenced documents except the contract. Any deviation from this specification, or from referenced documents where applicable, shall have the specific written approval of the procuring activity before adoption (see 6.2.1).

(c) Drawings. Except for the contract and this specification, the detailed drawing shall have precedence over all referenced documents listed on the detailed drawing.

4. QUALITY ASSURANCE PROVISIONS

4.1 General. This section establishes the requirements for verifying material conformance to the requirements of sections 3 and 5 by test, analysis, demonstration, or examination. The quality assurance provisions shall consist of the following classification of inspections and shall be as specified in table II.

(a) Preproduction inspection: (see 4.1.2.1)

(b) Periodic conformance inspection: (see 4.1.2.2)

(c) Quality conformance inspection: (see 4.2)

4.1.1 Responsibility for inspection: Unless otherwise specified in the contract or purchase order (see 6.2), the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the Government. The Government reserves the right to perform or witness any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to the prescribed requirements.

4.1.1.1 Inspection equipment, facilities, and conditions. Inspection equipment and facilities shall be of adequate quality and quantity to permit performance of the required examinations and tests. Unless otherwise specified, all examinations and tests shall be performed within the following ranges of ambient temperature, humidity, and pressure:

(a) Temperature: Plus 18 degrees to plus 35 degrees Centigrade (plus 65 degrees to plus 95 degrees, Fahrenheit)

(b) Relative humidity: Up to 95 percent

(c) Barometric pressure: Local average plus or minus 2 inches of mercury

4.1.1.2 Test equipment error. Equipment used to measure parameters shall introduce no overall errors greater than 10 percent of the tolerance. The test equipment error shall be applied to the specified parameter in such a manner as to assure that the specified parameter is being met. Test equipment calibration shall comply with the requirements of MIL-C-45662.

4.1.2 Special tests and examinations.

4.1.2.1 Pilot lot inspection. The pilot lot inspection shall consist of the inspections (see 6.3) specified in table II and shall consist of verification of the requirements of sections 3 and 5 by the methods specified in table II. Verification of the requirements shall be performed in a test sequence acceptable to the procuring activity. The pilot lot shall consist of 50 sheets, 24 inches by 36 inches, that have satisfactorily passed the quality conformance inspection of 4.2 and that have been subjected to the sampling specified in 4.1.2.1.1.

4.1.2.1.1 Pilot lot inspection sampling. Unless otherwise specified in the contract or purchase order (see 6.2), the pilot lot test items shall consist of eight sheets randomly selected from the pilot lot and subjected to the specified inspections of table II.

4.1.2.1.2 Action in case of pilot lot inspection failure. Failure of any material to meet one or more of the requirements specified for pilot lot inspection shall constitute a defective. If defectives are found during any inspection of table II, the pilot lot shall be rejected. The supplier shall then take corrective action that is acceptable to the procuring activity to correct the cause(s) for failure. Unless otherwise specified in the contract or purchase order (see 6.2), a subsequent production lot of material shall not be considered for acceptance until a pilot lot of material subjected to the inspections of 4.1.2.1 has satisfactorily passed the inspections following any corrective action.

4.1.2.2 Periodic conformance inspection. The periodic conformance inspections shall consist of the inspections specified in table II and shall consist of verification of the requirements specified by the methods noted therein. Verification of the requirements shall be performed in a test sequence acceptable to the procuring activity. Unless otherwise specified in the contract or purchase order (see 6.2), the periodic conformance inspection shall be performed on test items selected in accordance with 4.1.2.2.1.

4.1.2.2.1 Periodic conformance inspection sampling. The periodic conformance test items shall consist of eight sheets, 24 inches by 36 inches, randomly selected from the first lot of material submitted after 6 months from the successful completion of pilot lot inspection. Thereafter, no lot shall be shipped without first successfully passing the periodic conformance inspection if over 12 months have elapsed since the previous periodic conformance inspection was successfully completed. Each sheet shall have been subjected to the quality conformance inspections specified in table II.

4.1.2.2.2 Action in case of periodic conformance inspection failure. Failure of any test item to meet one or more of the requirements specified for periodic conformance inspection shall constitute a defective. If defectives are found, the supplier shall take corrective action acceptable to the procuring activity to correct the cause(s) for failure. Unless otherwise specified in the contract or purchase order (see 6.2), subsequent production materials shall not be considered for acceptance until all the test items subjected to the inspections of 4.1.2.2 have satisfactorily passed the inspections following any corrective action.

4.2 Quality conformance inspection. Quality conformance inspection shall consist of the inspections specified in table II for verification of the requirements by the methods noted therein. Unless otherwise specified in the contract or purchase order (see 6.2), the inspections may be performed in any sequence acceptable to the procuring activity. The quality conformance inspections shall be performed on each quality conformance lot.

4.2.1 Quality conformance inspection lot. The quality conformance inspection lot shall consist of material which has been manufactured in a single batch (see 6.3.5) under uniform conditions and is offered for inspection at any one time.

4.2.2 Quality conformance inspection sampling. The quality conformance inspection shall be performed on a sample inspection lot as specified in table II.

4.2.3 Inspection sample. Failure of any inspection, except those marked 2/ in table II, shall constitute rejection of the lot. In the event that inspections marked 2/ fail, the lot shall be inspected on a 100 percent basis for those failed attributes. Only defective material shall be rejected.

Table II. Test verification cross reference index

Verification method(s) legend: (see 6.3.3)	Test category legend:
1 - Test	A - Pilot lot inspection
2 - Review of analytical data and design	B - Periodic conformance inspection
3 - Demonstration	C - Quality conformance inspection
4 - Examination	

Requirement reference	1	2	3	4	A	B	C	QCI sample size	Inspection methods
3.1.2 Formulation		X			X		X	1/	4.3.1.1
3.1.3.1 Pits and dents				X	X		X	1/	4.3.1.2
3.1.3.2 Wrinkles 2/				X	X		X	1/	4.3.1.3
3.1.3.3 Thickness 2/				X	X		X	1/	4.3.1.4
3.1.4.1 Dielectric constant	X				X	X			4.3.2.1
3.1.4.2 Dissipation factor	X				X	X			4.3.2.2
3.1.4.3 Dielectric strength	X				X	X			4.3.2.3
3.1.4.4 Volume resistivity	X				X	X			4.3.2.4
3.1.4.5 Surface resistivity	X				X	X			4.3.2.4
3.1.4.6 Insulation resistance	X				X	X			4.3.2.5
3.1.4.7 Elongation	X				X	X			4.3.2.6
3.1.4.8 Peel strength after process exposure	X				X		X	1/	4.3.2.7
3.1.4.9 Flexural fatigue	X				X	X			4.3.2.8
3.1.5.1 Moisture absorption	X				X	X			4.3.3.1
3.1.5.2 Dimensional stability after thermal exposure	X				X	X			4.3.3.2

Table II. (Continued)

Verification method(s) legend: (see 6.3.3)	Test category legend:
1 - Test	A - Pilot lot inspection
2 - Review of analytical data and design	B - Periodic conformance inspection
3 - Demonstration	C - Quality conformance inspection
4 - Examination	

Requirement reference	1	2	3	4	A	B	C	QCI sample size	Inspection methods
3.1.5.3 Solder dip resistance	X				X		X	1/	4.3.3.3
3.1.5.4 Thermal shock resistance	X				X	X			4.3.3.4
3.1.5.5 Fungus resistance	X				X	X			4.3.3.5
3.1.7 Workmanship				X	X		X	1/	4.3.1.5
5. Preparation for delivery				X	X		X	1/	4.3.1.6

1/ Test samples of sufficient size to perform the indicated inspections shall be taken from each end of each batch.

2/ See 4.2.3 for lot accept/reject criteria.

4.2.4 Action in case of quality conformance inspection failure. In the event an inspection lot fails to comply with the lot sampling requirements specified herein, the supplier shall take corrective action acceptance to the procuring activity to correct the cause(s) for failure prior to performing any subsequent inspections.

4.3 Inspection methods. The inspection methods which follow are for demonstrating compliance with the requirements of sections 3 and 5. Alternate inspection methods may be proposed by the supplier but must be approved by the procuring activity prior to use in acceptance testing.

4.3.1 Physical, visual and analytical tests.

4.3.1.1 Formulation. Formulation shall be ascertained by the inspection of data that all materials and processes have been inspected and found to comply with their respective requirements specified in 3.1.2.

4.3.1.2 Pits and dents. The copper foil shall be examined in accordance with MIL-P-13949 to verify compliance with the requirements specified in 3.1.3.1.

4.3.1.3 Wrinkles. The material shall be examined in accordance with IPC-TM-650, section 2.1.5, to verify compliance with the requirements specified in 3.1.3.2.

4.3.1.4 Thickness. The material thickness shall be measured in accordance with ASTM D1000 to verify compliance with the requirements specified in 3.1.3.3.

4.3.1.5 Workmanship inspection. The material shall be examined for compliance with the workmanship requirements of 3.1.7.

4.3.1.6 Inspection for preparation for delivery. Inspection for compliance with the requirements of section 5 shall be performed on packages of material that have been prepared for delivery.

4.3.2 Functional tests.

4.3.2.1 Dielectric constant test. The material, with the copper removed, shall be tested in accordance with the dielectric constant test specified in ASTM D150 to verify compliance with the requirements specified in 3.1.4.1.

4.3.2.2 Dissipation factor test. The material, with the copper removed, shall be tested in accordance with the dissipation factor test specified in ASTM D150 to verify compliance with the requirements specified in 3.1.4.2.

4.3.2.3 Dielectric strength test. The material, with the copper removed, shall be tested in accordance with the dielectric strength test specified in ASTM D149 to verify compliance with the requirements specified in 3.1.4.3.

4.3.2.4 Volume resistivity and surface resistivity tests. The material, with the copper removed, shall be tested in accordance with the volume and surface resistivity tests specified in IPC-TM-650, section 2.5.17, to verify compliance with the requirements specified in 3.1.4.4 and 3.1.4.5.

4.3.2.5 Insulation resistance test. The material shall be tested in accordance with the insulation resistance test specified in IPC-TM-650, section 2.5.9, to verify compliance with the requirements specified in 3.1.4.6.

4.3.2.6 Copper foil elongation test. The copper foil shall be tested in accordance with the elongation test specified in IPC-TM-650, section 2.4.18, to verify compliance with the required specified in 3.1.4.7.

4.3.2.7 Peel strength after process exposure. The material shall be subjected to the process specified in 3.1.4.8, after which the peel strength of the material shall be determined as specified in IPC-TM-650, section 2.4.9, method C (except that line width shall be 0.125 inch), and section 2.4.13. A minimum of three 0.125-inch wide lines from the machine direction and three 0.125-inch wide lines from the transverse direction, for each side of the laminate, shall be subjected to test, to determine compliance with the requirements of 3.1.3.1. Failure of the substrate material, that is, Kapton tears or tensile failures at less than 7 pounds per inch of width, shall be considered an acceptable condition.

4.3.2.8 Flexural fatigue test. The material shall withstand the number of flexural cycles specified in 3.1.4.9 when tested in accordance with the flexural fatigue test specified in IPC-TM-650, section 2.4.3, method A, to verify compliance with the requirement specified in 3.1.4.9.

4.3.3 Environmental test methods.

4.3.3.1 Moisture absorption test. The material shall be tested in accordance with the moisture absorption test specified in IPC-TM-650, section 2.6.2, to verify compliance with the requirement specified in 3.1.5.1.

4.3.3.2 Dimensional stability after thermal exposure test. The material shall be tested in accordance with the dimensional stability test specified in IPC-TM-650, section 2.2.4, method C, to verify compliance with the requirements specified in 3.1.5.2.

4.3.3.3 Solder dip resistance test. The material shall be tested in accordance with the solder dip resistance test specified in IPC-TM-650 section 2.4.13, except the solder temperature and duration shall be plus 260 (plus or minus 5) degrees Centigrade [plus 500 (plus or minus 9) degrees Fahrenheit] for 10 seconds, minimum, to verify compliance with the requirement specified in 3.1.5.3.

4.3.3.4 Thermal shock resistance test. The material shall be tested in accordance with the thermal shock resistance test specified in IPC-TM-650, section 2.6.7, condition D, and MIL-STD-202, method 107, condition B to verify compliance with the requirement specified in 3.1.5.4.

4.3.3.5 Fungus resistance test. The material shall be tested in accordance with the fungus test specified in IPC-TM-650, section 2.6.1, to verify compliance with the requirement specified in 3.1.5.5.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging. Unless otherwise specified in the contract or purchase order (see 6.2), preservation and packaging shall be in accordance with 5.1.1.

5.1.1 Level C preservation and packaging. Preservation and packaging shall be in accordance with the supplier's commercial practices to afford protection from damage during shipment, within the scope of this specification, from the supply source to the first receiving activity.

5.2 Packing. Unless otherwise specified in the contract or purchase order (see 6.2), packing shall be in accordance with 5.2.1.

5.2.1 Level C packing. Materials packaged as specified shall be packed in containers of the type, size and kind commonly used for the purpose, in a manner that will insure acceptance by common carrier and safe delivery at destination. Shipping containers shall be in compliance with the Uniform Freight Classification Ratings, Rules, and Regulations, or the ratings, rules, and regulations for other carriers, as applicable to the mode of transportation.

5.3 Marking. Unless otherwise specified in the contract or purchase order (see 6.2) unit packages, intermediate packages, and exterior shipping containers shall be marked in accordance with MIL-STD-129. Each container shall be legibly marked with, but not limited to, the following information:

(a) Supplier's code identification

(b) Supplier's part number

(c) Dash number, for example: 18876-MIS 23659-004

6. NOTES

6.1 Intended use. The material covered by this specification is intended for use in the fabrication of flexible printed wiring.

6.2 Ordering data. Procurement documents should specify the following:

(a) Title, number and date of issue in effect of this specification.

(b) Responsibility for inspection, if other than that specified (see 4.1.1).

(c) Pilot lot inspection, whether required (see 4.1.2.1).

(d) Pilot lot inspection, any change in supplier's processes, or relocation of supplier's plant or facilities shall require performance of a new pilot lot inspection (see 4.1.2.1).

(e) Pilot lot inspection sampling, if other than that specified (see 4.1.2.1.1).

(f) Action in case of pilot lot inspection failure, if other than that specified (see 4.1.2.1.2).

(g) Periodic conformance inspection, if other than that specified (see 4.1.2.2).

(h) Action in case of periodic conformance inspection failure, if other than that specified (see 4.1.2.2.2).

(i) Quality conformance inspection, if other than that specified (see 4.2).

(j) Applicable level of preservation, packing, packaging, and marking, if other than that specified (see 5.1, 5.2 and 5.3).

6.2.1 Oral statement. No oral statement by any person or persons will be allowed in any manner or degree to modify or otherwise affect the requirements of any part of this specification, or any specification, standard, publication, drawing or document required herein.

6.3 Definitions. The following definitions apply to this specification when the terms defined are used herein.

6.3.1 Continuous production. Continuous production consists of a designated production line producing materials by means of the same processes, material requirements, controls, and design. Any recurring shutdown, such as weekends, holidays, or preventive maintenance of the line shall not affect the status of continuous production. Interruptions in production exceeding 30 calendar days, regardless of cause, shall terminate continuous production.

6.3.2 Inspections. When the term inspection is used herein, it is used as specified in MIL-STD-109.

6.3.3 Verification methods. The following definitions apply to the verification methods specified in table II.

(a) Tests. Tests are hose inspections which can be made by applying predetermined stimuli to the item under test and observing, measuring, or comparing the responses to ascertain that desired performance has been obtained.

(b) Review of analytical data and design. Review and analysis of engineering data to verify compliance as specified in table II.

(c) Demonstration. Verification of the compatibility of interfaces or actual operation of the equipment, or both.

(d) Examination. Examinations are those inspections which can be made by visual, tactile, or mechanical means to verify that requirements have been met.

6.3.4 Classifications of characteristics. Classifications of characteristics are defined in terms of severity of defects found in the test item as follows:

(a) Critical. A defect that judgment and experience indicate is likely to result in hazardous or unsafe conditions for individuals using, maintaining, or depending upon the product.

(b) Major. A defect that is likely to result in failure, or to reduce materially the usability of the unit of product for its intended purpose.

(c) Minor. A defect that is not likely to reduce materially the usability of the unit of product for its intended purpose, or is a departure from established standards having little bearing on the effective use or operation of the unit.

6.3.5 Batch. When the term batch is used herein, it is used as specified in MIL-STD-105.

6.4 Suggested source of supply. A suggested source of supply is as follows:

DuPont, E.I., DeNemours and Co., Inc.
Fabrics and Finishes Department
85 Mill Plain Road
Fairfield, Ct. 06430

Supplier's code ident: 90056
Supplier's part number:

LF9120R for -001
LF9121R for -002
LF9220R for -003
LF9222R for -004
LF9320R for -005
LF9323R for -006
LF9230R for -007
LF9232R for -008
LF9330R for -009
LF9333R for -010

6.4 Concluding page. The last page (including figures, tables, etcetera) of this specification includes an asterisk immediately to the right of the page number. The symbol indicates that nothing else follows that page.

Custodian:

ARMY - MI

Preparing activity:

U. S. Army Missile Research and
Development Command
Redstone Arsenal, Alabama 35809

GENERAL DYNAMICS
Pomona Division

TRANSMITTAL AND SIGNATURE SHEET

THIS SPECIFICATION IS PREPARED IN ACCORDANCE WITH THE REQUIREMENTS OF MIL-S-83490/MIL-STD-490 FOR A TYPE F, FORM 1b SPECIFICATION AS SPECIFIED IN ORDER OR CONTRACT NUMBER DAAK40-78-C-0118.

TITLE: Missile Research and Development Command Specification
Material Specification for
Insulating Sheet, Polyimide

MIS-23660

USED ON PROGRAM(S): Stinger

PAGES TOTAL: 21

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DRAWING: 13012499, 13012500, 11509539, 13012484 (Next assemblies)

TO BE RELEASED ON: A/C

GENERAL DYNAMICS POMONA DIVISION SIGNATURES:

PREPARED BY L. F. Cortina
L. F. Cortina

APPROVED BY
Production Integration

APPROVED BY
Design Group (133)

APPROVED BY
Materials and Processes

APPROVED BY
Quality Assurance

APPROVED BY Don L. VandeGriff 11/17/78
Program Office

Jack R. Detwiler
Reliability

CUSTOMER SIGNATURES

REPRESENTATIVE NR

ENGINEERING NR

APPROVAL NR

(3) FORM 9-775

ISSUE AND APPROVAL RECORD

ISSUE	DESCRIPTION	DATE
Original	This specification establishes the detail requirements and test methods for adhesive coated insulating sheet used in the fabrication of flexible printed wiring and multilayer flexible printed wiring. Approved ____________________ U. S. Army Missile Research and Development Command	

CODE IDENT
18876

MISSILE RESEARCH AND DEVELOPMENT COMMAND SPECIFICATION

MATERIAL SPECIFICATION FOR INSULATING SHEET, POLYIMIDE

1. SCOPE

1.1 This specification covers the detail requirements and test methods for adhesive coated polyimide insulating sheet, hereinafter referred to as the material.

2. APPLICABLE DOCUMENTS

2.1 Government documents. The following documents of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Military

MIL-C-45662	Calibration System Requirements
MIL-P-46112	Plastic Sheet and Strip, Polyimide

U.S. Army Missile Research and Development Command

MIS-23659	Material Specification for Insulating Sheet, Polyimide, Copper Clad
MIS-23661	Material Specification for Film, Adhesive

STANDARDS

Military

MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Identification and Marking of U.S. Military Property

(Copies of specifications, standards, and drawings required by suppliers in connection with specified procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Non-Government documents. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on the date of invitation for bids or request for proposal shall apply.

OTHER PUBLICATIONS

American Society for Testing and Materials

ASTM D149	Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies.
ASTM D150	A-C Loss Characteristics and Dielectric Constant (Permittivity) of Solid Electrical Insulating Materials.
ASTM D1000	Pressure-Sensitive Adhesive Coated Tapes Used for Electrical Insulation.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103).

Institute of Printed Circuits

IPC-TM-650	Test Methods Manual

(Application for copies should be addressed to the Institute of Printed Circuits, 1717 Howard Street, Evanston, Illinois 60202).

Uniform Classification Committee

Uniform Freight Classification	Ratings, Rules and Regulations

(Application for copies should be addressed to the Uniform Classification Committee, Tariff Agent, Room 1106, 222 South Riverside Plaza, Chicago, Illinois 60606).

3. REQUIREMENTS

3.1 General material requirements. The electrical, physical, and performance characteristics of the material shall be consistent as specified herein.

3.1.1 Electrical characteristics.

3.1.1.1 Dielectric strength. The dielectric strength of the material shall be 2000 volts, minimum, per mil of thickness.

3.1.1.2 Dielectric constant. The dielectric constant of the material shall be 4.0, maximum, at 100 kilohertz (kHz) and plus 25 (plus or minus 3) degrees Centigrade [plus 77 (plus or minus 5) degrees Fahrenheit].

3.1.1.3 Dissipation factor. The dissipation factor of the material shall be 0.1 maximum, at 100 kHz and plus 25 (plus or minus 3) degrees Centigrade [plus 77 (plus or minus 5) degrees Fahrenheit].

3.1.1.4 Volume resistivity. The volume resistivity of the material shall be 1.0 x 10^{12} ohms per centimeter, minimum.

3.1.1.5 Surface resistivity. The surface resistivity of the material shall be 1.0 x 10^{12} ohms per centimeter, minimum.

3.1.2 Physical characteristics.

3.1.2.1 Dimensional stability after thermal exposure. The dimensional change of the material shall be not more than 0.002 inch per inch, maximum, after exposure to plus 150 (plus or minus 2) degrees Centigrade [plus 302 (plus or minus 4) degrees Fahrenheit] for 30 (plus or minus 2) minutes.

3.1.2.2 Curl resistance. The material, with uncured adhesive, shall curl not more than 180 degrees.

3.1.2.3 Folding endurance. The material, with the adhesive cured, shall show no evidence of cracking after being folded at least 180 degrees.

3.1.2.4 Adhesive flow. The adhesive shall show full flow into all areas between 0.010-inch wide paths on 0.025 inch centers and 0.025-inch wide paths on 0.050 inch centers that have been etched into 2-ounce copper. The adhesive shall flow not more than 0.005 inch from the edge of a hole or slot.

3.1.2.5 Thickness. The thickness of the material shall be as specified in table I.

Table I. Insulating sheet thickness

Dash number	Side 1 adhesive thickness (mils)	Polyimide sheet thickness (mils)	Side 2 adhesive thickness (mils)
-001	2.0	1.0	None
-002	2.0	2.0	None
-003	2.0	3.0	None
-004	2.0	1.0	2.0
-005	2.0	2.0	2.0
-006	2.0	3.0	2.0

3.1.3 Performance characteristics.

3.1.3.1 Peel strength, laminated to untreated copper. When laminated to untreated (rolled annealed) copper, the material shall have a minimum peel strength of 7 pounds per inch of width and shall show no visible defects, after exposure to the following process:

(a) Application of suitable resist image and etch in ferric chloride etchant (P.A. Hunt Hi-Speed circuit etch, or equivalent) at plus 54 (plus or minus 6) degrees Centigrade [plus 130 (plus or minus 10) degrees Fahrenheit].

(b) Exposure to Riston 1100X (Du Pont) photo resist stripper at plus 74 (plus or minus 6) degrees Centigrade [plus 165 (plus or minus 10) degrees Fahrenheit].

(c) Presolder bake at plus 135 (plus or minus 6) degrees Centigrade [plus 275 (plus or minus 10) degrees Fahrenheit] in air, or at plus 77 (plus or minus 3) degrees Centigrade [plus 170 (plus or minus 5) degrees Fahrenheit] and minimum vacuum of 635 millimeters (25 inches) of mercury.

(d) Solder float in plus 288 (plus or minus 3)-degree Centigrade [plus 550 (plus or minus 5)-degree Fahrenheit] solder for 5 seconds, minimum.

3.1.3.2 Peel strength, copper removed. When laminated to copper-clad material (see MIS-23659) with the copper removed, the material shall have a minimum peel strength of 7 pounds per inch of width and shall show no visible evidence of delamination or blistering after a 5-second immersion in plus 288 (plus or minus 5)-degree Centigrade [plus 550 (plus or minus 3)- degree Fahrenheit] solder.

3.1.4 Environmental characteristics.

3.1.4.1 Moisture absorption. The moisture absorption of the material shall be 4 percent, maximum.

3.1.5 Workmanship. The material shall be clean and uniform in appearance and shall be free from inclusions, adhesive voids, and contamination. There shall be no wrinkles or tears in the material. The material may have either adhesive on one side only (for coverlay on external circuitry) or adhesive on both sides (for bondply to laminate two adjacent copper circuit layers together).

3.1.6 Identification and marking. The material shall be marked for identification in accordance with MIL-STD-130 by stamping or other permanent methods. Markings, paper labels or decalcomanias which will deteriorate due to environmental or other conditions specified herein shall not be used. Identification shall include the following:

(a) Specification number

(b) Supplier's designation

3.2 Materials.

3.2.1 Insulating sheet. The insulating sheet material shall be as specified in MIL-P-46112, type I.

3.2.2 Adhesive. The insulating sheet adhesive shall comply with MIS-23661, and shall yield a product that will meet the requirements specified herein.

3.3 Qualification.

3.3.1 Pilot lot. Unless otherwise specified in the contract or purchase order (see 6.2), a pilot lot shall be manufactured using the same methods and procedures proposed for production materials. Further production of the material prior to approval of the pilot lot shall be at the supplier's risk.

No design change shall be made after acceptance of the pilot lot without the prior approval of the procuring activity. Unless otherwise specified in the contract or purchase order, the following shall require performance of a pilot lot inspection (see 6.2):

(a) Original procurement

(b) Design change

(c) Break in production of greater than 6 months

(d) Relocation of supplier facilities

3.3.2 Periodic conformance. Unless otherwise specified in the contract or purchase order (see 6.2), quantities of the material shall be inspected after 6 months from the successful completion of pilot lot inspection, and if over 12 months have elapsed since the previous periodic conformance inspection was successfully completed for compliance with the requirements specified herein and subjected to the inspections as specified in 4.1.2.2.

3.4 Precedence. When the requirements of the contract, this specification, or applicable subsidiary specifications, standards, drawings, or other publications are in conflict, the following precedence shall apply:

(a) Contract. The contract shall have precedence over any other requirements.

(b) This specification. This specification shall have precedence over all referenced documents except the contract. Any deviation from this specification or from referenced documents, where applicable, shall have the written approval of the procuring activity before adoption (see 6.2.1).

(c) Drawings. Except for the contract and this specification the drawings shall have precedence over all referenced documents listed on the drawings.

4. QUALITY ASSURANCE PROVISIONS

4.1 General. This section establishes the procedures for verifying material conformance to the requirements of sections 3 and 5 by test or examination. The quality assurance provisions shall consist of the following classification of inspections and shall be as specified in table II.

(a) Pilot lot inspection: (see 4.1.2.1)

(b) Periodic conformance inspection: (see 4.1.2.2)

(c) Quality conformance inspection: (see 4.2)

4.1.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order (see 6.2), the supplier is responsible for the performance of all inspection (see 6.3) requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the procuring activity. The procuring activity reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1.1 Inspection equipment, facilities, and conditions. Inspection equipment and facilities shall be of adequate quality and quantity to permit performance of the required examinations and tests. Unless otherwise specified, all examinations and tests shall be performed within the following ranges of ambient temperature, humidity, and pressure:

(a) Temperature: Plus 18 degrees to plus 35 degrees Centigrade (plus 65 degrees to plus 95 degrees Fahrenheit).

(b) Relative humidity: Up to 95 percent.

(c) Barometric pressure: Local average plus or minus 2 inches of mercury.

4.1.1.2 Test equipment error. Equipment used to measure parameters shall introduce no overall errors greater than 10 percent of the tolerance. The test equipment error shall be applied to the specified parameter in such a manner as to assure that the specified parameter is being met. Test equipment calibration shall comply with the requirements of MIL-C-45662.

Table II. Test verification cross reference index

Verification method(s) legend: (see 6.3.2)	Test category legend:
1. Test 2. Examination	A - Pilot lot inspection B - Periodic conformance inspection C - Quality conformance inspection

Requirement reference		1	2	A	B	C	Sample size	Inspection methods
3.1.1.1	Dielectric strength	X		X		X	4/	4.3.2.1
3.1.1.2	Dielectric constant	X		X	X			4.3.2.2
3.1.1.3	Dissipation factor	X		X	X			4.3.2.3
3.1.1.4	Volume resistivity	X		X		X	4/	4.3.2.4
3.1.1.5	Surface resistivity	X		X	X			4.3.2.5
3.1.2.1	Dimensional stability after thermal exposure	X		X	X			4.3.1.1
3.1.2.2	Curl resistance			X		X	4/	4.3.1.2
3.1.2.3	Folding endurance	X		X	X			4.3.1.3
3.1.2.4	Adhesive flow	X		X		X	4/	4.3.1.4
3.1.2.5	Thickness 3/	X		X		X	4/	4.3.1.5
3.1.3.1	Peel strength, laminated to untreated copper 1/	X		X		X	4/	4.3.1.6.1
3.1.3.2	Peel strength, copper removed 2/	X		X		X	4/	4.3.1.6.2
3.1.4.1	Moisture absorption	X		X	X			4.3.3.1
3.1.5	Workmanship		X	X		X	4/	4.3.1.8
3.2	Materials		X	X	X			4.3.1.7
5.	Preparation for delivery		X	X		X	4/	4.3.1.9

1/ Untreated copper (see MIS-23659).
2/ Copper clad material with the copper removed (see MIS-23659).
3/ See 4.2.3 for lot accept/reject criteria.
4/ Test samples of sufficient size to perform the indicated inspections shall be taken from each end of each batch.

4.1.2 Special tests and examinations.

4.1.2.1 Pilot lot inspection. The pilot lot inspection shall consist of the inspections (see 6.3.1) specified in table II and shall consist of verification of the requirements of sections 3 and 5 by the methods specified in table II. Verification of the requirements shall be performed in a test sequence acceptable to the procuring activity. The pilot lot shall consist of 50 sheets, 24 inches by 36 inches, that have satisfactorily passed the quality conformance inspection of 4.2 and that have been subjected to the sampling specified in 4.1.2.1.1.

4.1.2.1.1 Pilot lot inspection sampling. Unless otherwise specified in the contract or purchase order (see 6.2), the pilot lot test items shall consist of five sheets randomly selected from the pilot lot and subjected to the specified inspections of table II.

4.1.2.1.2 Action in case of pilot lot inspection failure. Failure of any material to meet one or more of the requirements specified for pilot lot inspection shall constitute a defective. If defectives are found during any inspection of table II, the pilot lot shall be rejected. The supplier shall then take corrective action that is acceptable to the procuring activity to correct the cause(s) for failure. Unless otherwise specified in the contract or purchase order (see 6.2), a subsequent production lot of material shall not be considered for acceptance until a pilot lot of material subjected to the inspections of 4.1.2.1 has satisfactorily passed the inspections following any corrective action.

4.1.2.2 Periodic conformance inspection. The periodic conformance inspections shall consist of the inspections specified in table II and shall consist of verification of the requirements specified by the methods noted therein. Verification of the requirements shall be performed in a test sequence acceptable to the procuring activity. Unless otherwise specified in the contract or purchase order (see 6.2), the periodic conformance inspection shall be performed on test items selected in accordance with 4.1.2.2.1.

4.1.2.2.1 Periodic conformance inspection sampling. The periodic conformance test items shall consist of five sheets, 24 inches by 36 inches, randomly selected from the first lot of material submitted after 6 months from the successful completion of pilot lot inspection. Thereafter, no lot shall be shipped without first successfully passing the periodic conformance inspection if over 12 months have elapsed since the previous periodic conformance

inspection was successfully completed. Each sheet shall have been subjected to the quality conformance inspections specified in table II.

4.1.2.2.2 Action in case of periodic conformance inspection failure. Failure of any test item to meet one or more of the requirements specified for periodic conformance inspection shall constitute a defective. If defectives are found, the supplier shall take corrective action acceptable to the procuring activity to correct the cause(s) for failure. Unless otherwise specified in the contract or purchase order (see 6.2), subsequent production materials shall not be considered for acceptance until all the test items subjected to the inspections of 4.1.2.2 have satisfactorily passed the inspections following any corrective action.

4.2 Quality conformance inspection. Quality conformance inspection shall consist of the inspections specified in table II for verification of the requirements by the methods noted therein. Unless otherwise specified in the contract or purchase order (see 6.2), the inspections may be performed in any sequence acceptable to the procuring activity. The quality conformance inspections shall be performed on each quality conformance lot.

4.2.1 Quality conformance inspection lot. The quality conformance inspection lot shall consist of material which has been manufactured in a single batch (see 6.3.3) under uniform conditions and is offered for inspection at any one time.

4.2.2 Quality conformance inspection sampling. The quality conformance inspection shall be performed on a sample inspection lot as specified in table II.

4.2.3 Inspection sample. Failure of any inspection, except thickness, shall constitute rejection of the lot. If the material fails the thickness inspection, the lot shall be inspected on a 100-percent basis for the failed attribute. Only defective material shall be rejected.

4.2.4 Action in case of quality conformance inspection failure. If an inspection lot fails to comply with the lot sampling requirements specified herein, the supplier shall take corrective action acceptable to the procuring activity to correct the cause(s) for failure prior to performing any subsequent inspections.

4.3 Inspection methods. The inspection methods which follow are for demonstrating compliance with the requirements of sections 3 and 5. Alternate inspection methods may be proposed by the supplier but shall be subject to approval by the procuring activity prior to use in acceptance testing.

4.3.1 Physical, visual, and analytical inspections.

4.3.1.1 Dimensional stability after thermal exposure test. The dimensional stability of the material after thermal exposure shall be determined as specified in IPC-TM-650, section 2.2.4, to verify compliance with the requirements of 3.1.2.1.

4.3.1.2 Curl resistance test. The curl resistance of the material shall be determined as specified in IPC-TM-650, section 2.4.22, to verify compliance with the requirements of 3.1.2.2.

4.3.1.3 Folding endurance test. The folding endurance of the material shall be determined as specified in IPC-TM-650, section 2.4.5, to verify compliance with the requirements of 3.1.2.3.

4.3.1.4 Adhesive flow test. Using the test pattern shown in figure 2 and the supplier's recommended laminating process, the material shall be bonded to the copper. The etched lines shall be cross-sectioned perpendicular to the longitudinal axis of the lines and examined at a magnification of 100 power for full adhesive flow. The four hole patterns of each hole size and the tapered slot shall be examined to verify compliance with the requirements of 3.1.2.4.

4.3.1.5 Thickness test. The material thickness shall be determined as specified in the material thickness test of ASTM D1000 to verify compliance with the requirements of 3.1.2.5.

4.3.1.6 Peel strength tests. (For sample preparation, see figure 1).

4.3.1.6.1 Peel strength after process exposure. The material shall be subjected to the process specified in 3.1.3.1 after which the peel strength of the material shall be determined as specified in IPC-TM-650, section 2.4.9, method C (except that line width shall be 0.125 inch), and section 2.4.13. A minimum of three 0.125-inch wide lines from the machine direction and three 0.125-inch wide lines from the transverse direction, ior each side of the laminate, shall be subjected to test, to determine compliance with the requirements of 3.1.3.1. Failure of the substrate material, that is, Kapton tears or tensile failures at less than 7 pounds per inch of width, shall be considered an acceptable condition.

4.3.1.6.2 Peel strength after solder immersion. The peel strength of the material after solder immersion shall be determined as specified in IPC-TM-650, sections 2.4.13 and 2.4.9, method A, to verify compliance with the requirements of 3.1.3.2. Failure of the substrate material, that is, Kapton tears or tensile failures at less than 7 pounds per inch of width, shall be considered an acceptable condition.

4.3.1.7 Materials and processes. It shall be determined by the inspection of data that all material has been inspected and found to comply with the requirements of 3.2, and that all specified manufacturing processes have been followed during production.

4.3.1.8 Workmanship inspection. The material shall be examined for compliance with the workmanship requirements of 3.4.

4.3.1.9 Inspection of preparation for delivery. Packages of the material prepared for delivery shall be inspected for compliance with the cleaning, preservation, packaging, packing, and marking requirements of 5.1 through 5.3.

4.3.2 Electrical tests.

4.3.2.1 Dielectric strength test. The material shall be tested in accordance with the dielectric strength test specified in ASTM D149 to verify compliance with the requirements specified in 3.1.1.1.

4.3.2.2 Dielectric constant test. The material shall be tested in accordance with the dielectric constant test specified in ASTM D150 to verify compliance with the requirements specified in 3.1.1.2.

4.3.2.3 Dissipation factor test. The material shall be tested in accordance with the dissipation factor test specified in ASTM D150 to verify compliance with the requirements specified in 3.1.1.3.

4.3.2.4 Volume resistivity test. The material shall be tested in accordance with the volume resistivity test specified in IPC-TM-650, section 2.5.17, to verify compliance with the requirements specified in 3.1.1.4.

4.3.2.5 Surface resistivity test. The material shall be tested in accordance with the surface resistivity test specified in IPC-TM-650, section 2.5.17, to verify compliance with the requirements specified in 3.1.1.5.

4.3.3 Environmental test.

4.3.3.1 Moisture absorption test. The material shall be tested in accordance with the moisture absorption test specified in IPC-TM-650, section 2.6.2, to verify compliance with the requirements specified in 3.1.4.1.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging. Unless otherwise specified in the contract or purchase order (see 6.2), preservation and packaging shall be in accordance with 5.1.1.

5.1.1 Level C preservation and packaging. Preservation and packaging shall be in accordance with the supplier's commercial practices to afford protection from damage during shipment, within the scope of this specification, from the supply source to the first receiving activity.

5.2 Packing. Unless otherwise specified in the contract or purchase order (see 6.2), packing shall be in accordance with 5.2.1.

5.2.1 Level C packing. The material packaged as specified shall be packed in containers of the type, size, and kind commonly used for the purpose, in a manner that will ensure acceptance by common carrier and safe delivery at destination. Shipping containers shall be in compliance with the Uniform Freight Classification ratings, rules, and regulations, or the ratings, rules, and regulations for other carriers, as applicable to the mode of transportation.

5.3 Marking. Unless otherwise specified in the contract or purchase order (see 6.2), unit packages, intermediate packages, and exterior shipping containers shall be marked in accordance with MIL-STD-129 (and shall include, but not be limited to, Code Ident., Part No., and applicable Dash No. Example: 18876-MIS 23660-001.)

6.2.1 Oral statements. No oral statement by any person or persons will be allowed in any manner or degree to modify or otherwise affect the requirements of any part of this specification, standard, publication, drawing, or document required herein.

6.3 Definitions. The following definitions apply to this specification.

6.3.1 Inspections. When the term inspection is used herein, it is used as specified in MIL-STD-109.

6.3.2 Verification methods. The following definitions apply to the verification methods specified in table II.

(a) Test - Tests are those inspections which can be made by applying predetermined stimuli to the item under test and observing, measuring, or comparing the responses to ascertain that desired performance has been obtained.

(b) Examination - Examinations are those inspections which can be made by visual, tactile, or mechanical means to verify that requirements have been met.

6.3.3 Batch. When the term batch is used herein, it is used as specified in MIL-STD-105.

6.4 Suggested source(s) of supply:

Du Pont, E.I., DeNemours and Co., Inc.
Fabrics and Finishes Department
85 Mill Plain Road
Fairfield, Ct. 06430

Supplier's code ident: 90056

Supplier's part number:

LF 0210 for -001
LF 0220 for -002
LF 0230 for -003
LF 0212 for -004
LF 0222 for -005
LF 0232 for -006

6.5 Concluding page. The last page (including figures, tables, etc.) of this specification includes an asterisk immediately to the right of the page number. The symbol indicates that nothing else follows that page.

Custodian:	Preparing activity:
Army - MI	U.S. Army Missile Research and Development Command Redstone Arsenal, Alabama 35809

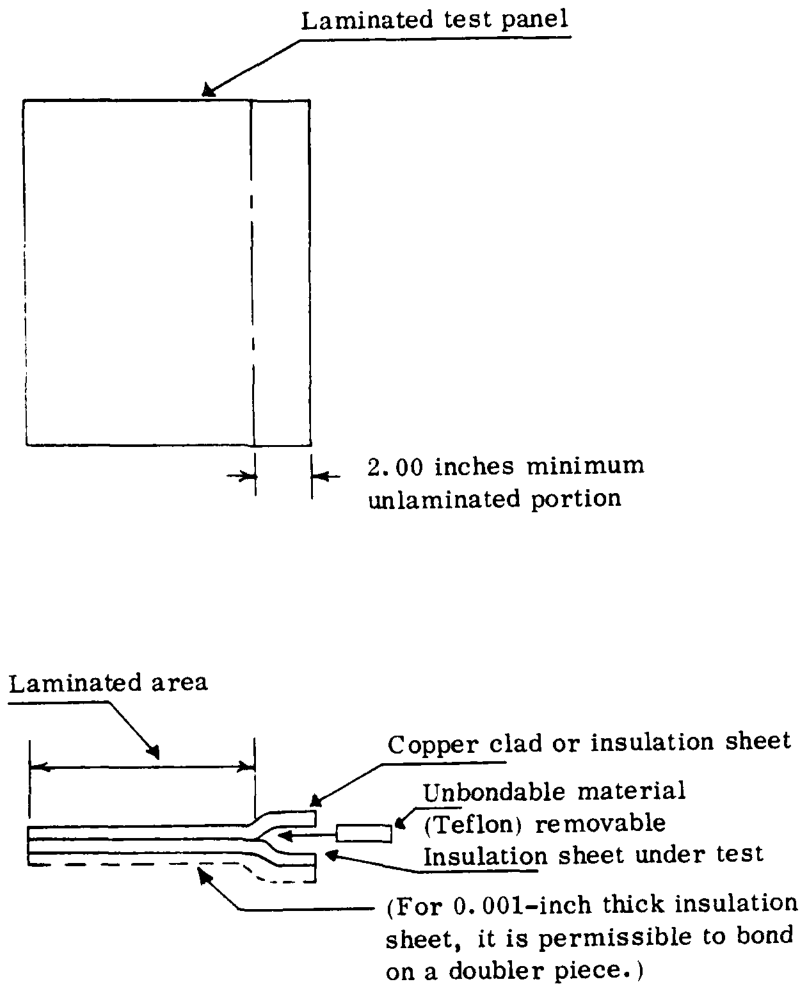
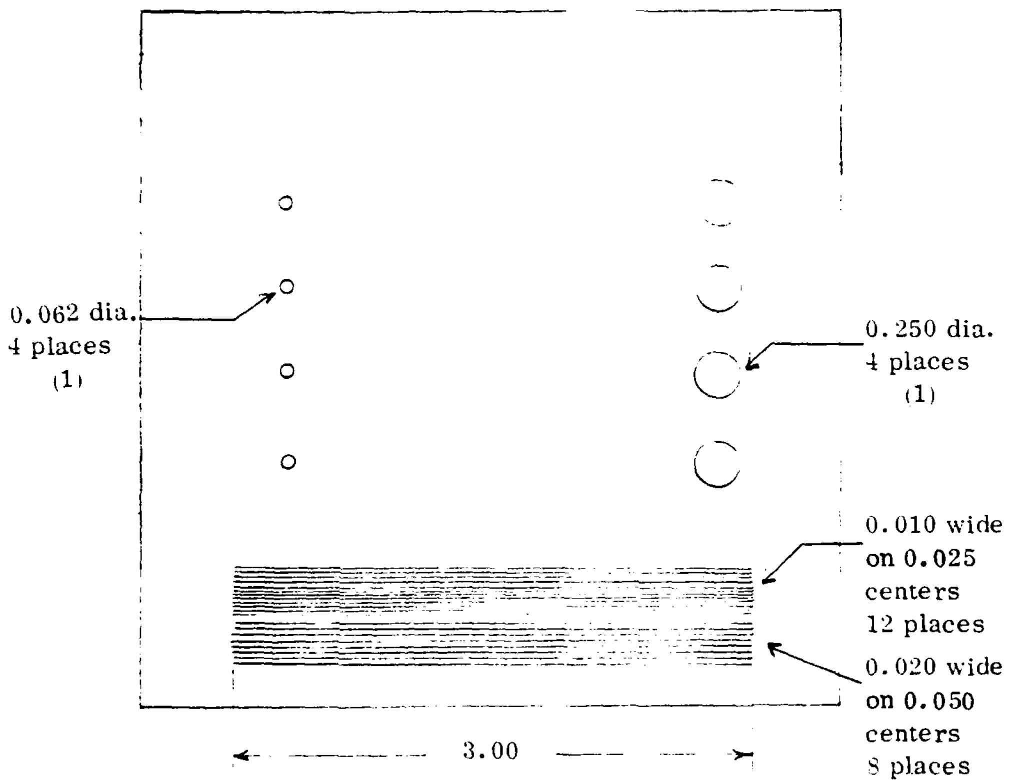


Figure 1. Peel strength test preparation



(1) Through insulation sheet only

Note: Dimensions are in inches

Figure 2. Adhesive flow test pattern

AD-A095 045 GENERAL DYNAMICS CORP POMONA CA POMONA DIV F/G 9/5
RIGID-FLEX PRINTED CIRCUIT MANUFACTURING PROCESS. A PROJECT OF --ETC(U)
JUN 79 J A REAVILL N00123-77-C-1192
UNCLASSIFIED NAVSEA-MT-S-479-77 NL

4 OF 5
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GENERAL DYNAMICS
Pomona Division

TRANSMITTAL AND SIGNATURE SHEET

THIS SPECIFICATION IS PREPARED IN ACCORDANCE WITH THE REQUIREMENTS OF MIL-S-83490/MIL-STD-490 FOR A TYPE E, FORM 1b SPECIFICATION AS SPECIFIED IN ORDER OR CONTRACT NUMBER DAAK40-78-C-0118.

TITLE: Missile Research and Development Command Specification
Material Specification for Film, Adhesive MIS-23661

USED ON PROGRAM(S): Stinger

PAGES TOTAL: 21

DATE: 10 November 1978

DRAWING: MIS-23659, MIS-23660 (Next assemblies)

TO BE RELEASED ON:

GENERAL DYNAMICS POMONA DIVISION SIGNATURES:

____
Reliability

PREPARED BY L. F. Cortina
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APPROVED BY ______________________
Design Group (133)

APPROVED BY ______________________
Materials and Processes

APPROVED BY ______________________
Quality Assurance

APPROVED BY ______________________ 11/17/78
Program Office

CUSTOMER SIGNATURES

REPRESENTATIVE NR

ENGINEERING NR

APPROVAL NR

GDI FORM 5-775

ISSUE AND APPROVAL RECORD

ISSUE	DESCRIPTION	DATE
Original	This material specification establishes the material requirements and acceptance tests for adhesive film. APPROVED ______________________ U.S. Army Missile Research and Development Command	

CODE IDENT
18876

MISSILE RESEARCH AND DEVELOPMENT

COMMAND SPECIFICATION

MATERIAL SPECIFICATION FOR

FILM, ADHESIVE

1. SCOPE

1.1 This specification specifies the material requirements and acceptance tests for adhesive film used in the fabrication of flexible printed wiring (FPW).

2. APPLICABLE DOCUMENTS

2.1 Government documents. The following documents, of the issue in effect on the data of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Military

MIL-C-45662	Calibration System Requirements

U. S. Army Missile Research and Development Command

MIS-23659	Material Specification for Insulating Sheet, Polyimide, Copper Clad

STANDARDS

Military

MIL-STD-129	Marking for Shipment and Storage

MIL-STD-130	Identification and Marking of U.S. Military Property

2.2 Non-Government documents. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on the data of invitation for bids or request for proposal shall apply.

OTHER PUBLICATIONS

Americal Society for Testing and Materials

ASTM D149	Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies
ASTM D150	A-C Loss Characteristics and Dielectric Constant (Permittivity) of Solid Electrical Insulating Materials
ASTM D257	D-C Resistance or Conductance of Insulating Materials
ASTM D1000	Pressure-Sensitive Adhesive Coated Tapes Used for Electrical Insulation

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. 19103).

Institute of Printed Circuits

IPC-TM-650	Test Methods Manual

(Application for copies should be addressed to the Institute of Printed Circuits, 1717 Howard Street, Evanston, Illinois 60202).

Uniform Classification Committee

Uniform Freight Classification	Ratings, Rules and Regulations

(Application for copies should be addressed to the Uniform Classification Committee, Room 1106, 222 South Riverside Plaza, Chicago, Illinois 60606.)

3. REQUIREMENTS

3.1 General material requirements. The electrical, physical, and performance properties of adhesive film covered herein shall be consistent and as defined in this specification. The material shall be clean and uniform in appearance; it shall be free of voids, contamination, tears, wrinkles, and other surface irregularities.

3.1.1 Adhesive. The adhesive shall yield a product that will meet the requirements specified herein.

3.1.2 Product characteristics. The material shall comply with the product characteristics specified in 3.1.2.1 through 3.1.2.3.

3.1.2.1 Adhesive flow. The adhesive shall show full flow into all areas between 0.010-inch wide paths on 0.025-inch centers and 0.025-inch wide paths on 0.050-inch centers that have been etched using 2-ounce copper. The adhesive shall not flow more than 0.005-inch from the edge of a hole or slot.

3.1.2.2 Curl resistance. The material shall lie in a flat position.

3.1.2.3 Thickness. The thickness of the material shall be 0.002 (plus or minus 0.001) inch.

3.1.3 Chemical, electrical, and mechanical properties.

3.1.3.1 Electrical characteristics. The material shall comply with the electrical characteristics specified in 3.1.3.1.1 through 3.1.3.1.5.

3.1.3.1.1 Dielectric constant. The dielectric constant of the material shall be 4.0 maximum at 100 kilohertz and 25 degrees Centigrade (77 degrees Fahrenheit).

3.1.3.1.2 Dissipation factor. The dissipation factor of the material shall be 0.1 maximum at 100 kilohertz and 25 degrees Centigrade.

3.1.3.1.3 Dielectric strength. The dielectric strength of the material shall be 1900 volts minimum per mil of thickness.

3.1.3.1.4 Volume resistivity. The volume resistivity of the material shall be 1 x 10^{12} ohms/centimeter, minimum.

3.1.3.1.5 Surface resistivity. The surface resistivity of the material shall be 1 x 10^{12} ohms/centimeter, minimum.

3.1.4 Performance characteristics.

3.1.4.1 Peel strength, laminated to untreated copper. When laminated to untreated (rolled annealed) copper, the material shall have a minimum peel strength of 7 pounds per inch of width and shall show no visible defects, after exposure to the following process:

(a) Application of suitable resist image and etch in ferric chloride etchant (P. A. Hunt Hi-Speed circuit etch, or equivalent) at plus 54 (plus or minus 6) degrees Centigrade [plus 130 (plus or minus 10) degrees Fahrenheit].

(b) Exposure to Riston 1100X (Du Pont) photo resist stripper at plus 74 (plus or minus 6) degrees Centigrade [plus 165 (plus or minus 10) degrees Fahrenheit].

(c) Presolder bake at plus 135 (plus or minus 6) degrees Centigrade [plus 275 (plus or minus 10) degrees Fahrenheit] in air, or at plus 77 (plus or minus 3) degrees Centigrade [plus 170 (plus or minus 5) degrees Fahrenheit] and minimum vacuum of 635 millimeters (25 inches) of mercury.

(d) Solder float in plus 288 (plus or minus 3)-degree Centigrade [plus 550 (plus or minus 5)-degree Fahrenheit] solder for 5 seconds, minimum.

3.1.4.2 Peel strength, copper removed. When laminated to copperclad material (see MIS-23659) with the copper removed, the material shall have a minimum peel strength of 7 pounds per inch of width and shall show no visible evidence of delamination or blistering after a 5-second immersion in plus 288 (plus or minus 5)-degree Centigrade [plus 550 (plus or minus 3)-degree Fahrenheit] solder.

3.1.5 Identification and marking. The adhesive film shall be marked for identification in accordance with MIL-STD-130 by stamping or other permanent methods. Markings, paper labels, or decalcommias which will deteriorate due to environmental or other conditions specified herein, shall not be used. Identification shall evaluate the following:

(a) Specification number

(b) Supplier's designations

3.1.6 Workmanship. All adhesive film shall be finished in a thoroughly workmanlike manner, clean, uniform in appearance, free from wrinkles and defects.

3.2 Qualification.

3.2.1 Pilot lot. Unless otherwise specified in the contract or purchase order (see 6.2), a pilot lot shall be manufactured using the same methods and procedures proposed for production materials. Further production of the materials prior to approval of the pilot lot shall be at the supplier's risk. No design change shall be made after acceptance of the pilot lot without the prior approval of the procuring activity. Unless otherwise specified in the contract or purchase order, the following shall require performance of a pilot lot inspection (see 6.2):

(a) Original procurement

(b) Design change

(c) Break in production of greater than 6 months

(d) Relocation of supplier facilities

3.2.2 Periodic conformance. Unless otherwise specified in the contract or purchase order (see 6.2), quantities of film shall be inspected after 6 months from the successful completion of pilot lot inspection, and if over 12 months have elapsed since the previous periodic conformance inspection was successfully completed, for compliance with the requirements specified herein and subjected to the inspections as specified in 4.2.2.

3.3 Precedence. When the requirements of the contract, this specification, or applicable subsidiary specifications, standards, drawings, or other publications are in conflict, the following precedence shall apply:

(a) Contract. The contract shall have precedence over any other requirements.

(b) This specification. This specification shall have precedence over all referenced documents except the contract. Any deviation from this specification, or from referenced documents where applicable, shall have the specific written approval of the procuring activity before adoption (see 6.2).

(c) Drawings. Except for the contract and this specification, the detailed drawing shall have precedence over all referenced documents listed on the detailed drawing.

4. QUALITY ASSURANCE PROVISIONS

4.1 General. This section establishes the procedures for verifying material conformance to the requirements of sections 3 and 5 by test, analysis, demonstration, or examination. The quality assurance provisions shall consist of the following classification of inspections and shall be as specified in table I.

(a) Pilot lot inspection: (see 4.2.1)

(b) Periodic conformance inspection: (see 4.2.2)

(c) Quality conformance inspection: (see 4.3)

4.1.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the procuring activity. The procuring activity reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1.1 Inspection equipment, facilities, and conditions. Inspection equipment and facilities shall be of adequate quality and quantity to permit performance of the required examinations and tests. Unless otherwise specified, all examinations and tests shall be performed within the following ranges of ambient temperature, humidity, and pressure:

(a) Temperature: Plus 18 degrees to plus 35 degrees Centigrade (plus 65 degrees to plus 95 degrees Fahrenheit)

(b) Relative humidity: Up to 95 percent

(c) Barometric pressure: Local average plus or minus 2 inches of mercury.

Table I. Test verification cross reference index

Verification method(s) legend:	Test category legend:
1 - Test	A - Pilot lot inspection
2 - Review of analytical data and design	B - Periodic conformance inspection
3 - Demonstration	C - Reliability assurance inspection
4 - Examination	D - Quality conformance inspection

Section 3 Requirement reference		1	2	3	4	A	B	C	D	AQL or percent inspection	Inspection methods
3.1	Visual examination				X	X			X	4/	4.4.1.1
3.1.3.1.1	Dielectric constant	X				X	X				4.4.2.1
3.1.3.1.2	Dissipation factor	X				X	X				4.4.2.2
3.1.3.1.3	Dielectric strength	X				X	X				4.4.2.3
3.1.3.1.4	Volume resistivity	X				X	X				4.4.2.4
3.1.3.1.5	Surface resistivity	X				X	X				4.4.2.5
3.1.2.1	Adhesive flow	X				X			X	4/	4.4.3.1
3.1.2.2	Curl resistance 1/	X				X			X	4/	4.4.3.2
3.1.2.3	Thickness 1/	X				X			X	4/	4.4.3.3
3.1.4.1	Peel strength, laminated to untreated copper 2/	X				X			X	4/	4.4.4.1
3.1.4.2	Peel strength copper removed 3/	X				X			X	4/	4.4.4.2
3.1.6	Workmanship				X	X			X	4/	4.4.4.5
5.	Preparation for delivery				X	X			X	4/	4.4.4.6

1/ See 4.3.3 for lot accept/reject criteria.

2/ Untreated rolled annealed copper (see MIS-23659).

3/ Copper laminate (see MIS-23659) with copper removed.

4/ Test samples of sufficient size to perform the indicated inspections shall be taken from each end of each batch.

4.1.2 Test equipment error. Equipment used to measure parameters shall introduce no overall errors greater than 10 percent of the tolerance. The test equipment error shall be applied to the specified parameter in such a manner as to assure that the specified parameter is being met. Test equipment calibration shall comply with the requirements of MIL-C-45662.

4.2 Special tests and examinations. The material shall be subjected to the special tests and examinations specified in 4.2.1 and 4.2.2.

4.2.1 Pilot lot inspection. Unless otherwise specified in the contract or purchase order (see 6.2) a pilot lot shall be manufactured using the same methods and procedures proposed for production materials. Further production of the materials prior to approval of the pilot lot shall be at the supplier's risk. No design change shall be made after acceptance of the pilot lot without the prior approval of the procuring activity. Unless otherwise specified in the contract or purchase order, the following shall require performance of a pilot lot inspection:

(a) Original procurement

(b) Design change

(c) Break in production of greater than 6 months

(d) Relocation of supplier facilities

The pilot lot inspection shall consist of the inspections (see 6.4.) specified in table I and shall consist of verification of the requirements of sections 3 and 5 by the methods specified in table I. Verification of the requirements shall be performed in a test sequence acceptable to the procuring activity. The pilot lot shall consist of 50 sheets, 24 inches x 36 inches, that have satisfactorily passed the quality conformance inspection of 4.2 and that have been subjected to the sampling specified in 4.2.1.1.

4.2.1.1 Pilot lot inspection sampling. Unless otherwise specified in the contract or purchase order (see 6.2), the pilot lot test items shall consist of 5 sheets randomly selected from the pilot lot and subjected to the specified inspections of table I.

4.2.1.2 Action in case of pilot lot inspection failure. Failure of any material to meet one or more of the requirements specified for pilot lot inspection shall constitute a defective. If defectives are found during any inspection of table I, the pilot lot shall be rejected. The supplier shall then take corrective action that is acceptable to the procuring activity to correct the cause(s) for failure. Unless otherwise specified in the contract or purchase order (see 6.2), a subsequent production lot of material shall not be considered for acceptance until a pilot lot of material subjected to the inspections of 4.2.1 has satisfactorily passed the inspections following any corrective action.

4.2.2 Periodic conformance inspection. The periodic conformance inspections shall consist of the inspections specified in table I and shall consist of verification of the requirements specified by the methods noted therein. Verification of the requirements shall be performed in a test sequence acceptable to the procuring activity. Unless otherwise specified in the contract or purchase order (see 6.2), the periodic conformance inspection shall be performed on test items selected in accordance with 4.2.2.1.

4.2.2.1 Periodic conformance inspection sampling. The periodic conformance test items shall consist of 5 sheets, 24 inches x 36 inches, randomly selected from the first lot of material submitted after 6 months from the successful completion of pilot lot inspection. Thereafter, no lot shall be shipped without first successfully passing the periodic conformance inspection if over 12 months have elapsed since the previous periodic conformance inspection was successfully completed. Each sheet shall have been subjected to the quality conformance inspections specified in table I.

4.2.2.2 Action in case of periodic conformance inspection failure. Failure of any test item to meet one or more of the requirements specified for periodic conformance inspection shall constitute a defective. If defectives are found, the supplier shall take corrective action acceptable to the procuring activity to correct the cause(s) for failure. Unless otherwise specified in the contract or purchase order (see 6.2), subsequent production materials shall not be considered for acceptance until all the test items subjected to the inspections of 4.2.2 have satisfactorily passed the inspections following any corrective action.

4.3 Quality conformance inspection. Quality conformance inspection shall consist of the inspections specified in table I for verification of the requirements by the methods noted therein. Unless otherwise specified in the contract or purchase order (see 6.2), the inspections may be performed in any sequence acceptable to the procuring activity. The quality conformance inspections shall be performed on each quality conformance lot.

4.3.1 Quality conformance inspection lot. The quality conformance inspection lot shall consist of material which has been manufactured in a single batch (see 6.4.3) under uniform conditions and is offered for inspection at any one time.

4.3.2 Quality conformance inspection sampling. The quality conformance inspection shall be performed on a sample inspection lot as specified in table I.

4.3.3 Inspection sample. Failure of any inspection, except those marked 1/in table I, shall constitute rejection of the lot. In the event that inspections marked 1/fail, the lot shall be inspected on a 100 percent basis for those failed attributes. Only defective material shall be rejected.

4.3.4 Action in case of quality conformance inspection failure. In the event an inspection lot fails to comply with the lot sampling requirements specified herein, the supplier shall take corrective action acceptable to the procuring activity to correct the cause(s) for failure prior to performing any subsequent inspections.

4.4 Inspection methods. The inspection methods which follow are for demonstrating compliance with the requirements of sections 3 and 5. Alternate inspection methods may be proposed by the supplier but shall be subject to approval by the procuring activity prior to use in acceptance testing.

4.4.1 Physical, visual and analytical inspections.

4.4.1.1 Visual inspection. The material shall be visually inspected for conformance to the requirements of 3.1.

4.4.2 Electrical tests.

4.4.2.1 Dielectric constant. The dielectric constant shall be tested in accordance with ASTM D150 to determine compliance with the requirement specified in 3.1.3.1.1.

4.4.2.2 Dissipation factor. The dissipation factor shall be tested in accordance with ASTM D150 to determine compliance with the requirement specified in 3.1.3.1.2.

4.4.2.3 Dielectric strength. The dielectric strength shall be tested in accordance with ASTM D149 to determine compliance with the requirement specified in 3.1.3.1.3.

4.4.2.4 Volume resistivity. The volume resistivity shall be tested in accordance with ASTM D257 to determine compliance with the requirement specified in 3.1.3.1.4.

4.4.2.5 Surface resistivity. The surface resistivity shall be tested in accordance with IPC-TM-650, section 2.5.17, to determine compliance with the requirement specified in 3.1.3.1.5.

4.4.3 Physical characteristics.

4.4.3.1 Adhesive flow. Using figure 2 test pattern and the supplier's recommended laminating process, a 2-mil thick insulation sheet shall be bonded to the copper using one sheet of adhesive film. The etched lines shall be cross-sectioned perpendicular to the longitudinal axis of the lines and examined at a magnification of 100 power for full adhesive flow. All four hole patterns of each hole size and the tapered slot shall be examined for excessive adhesive flow.

4.4.3.2 Curl resistance. The curl resistance of the material shall be stabilized for a 24 hour maximum period with the backing removed, to determine compliance with the requirement specified in 3.1.2.2.

4.4.3.3 Thickness. The material thickness shall be tested in accordance with ASTM D1000 to determine compliance with the requirement specified in 3.1.2.3.

4.4.4 Performance tests (see figure 1 for sample layup).

4.4.4.1 Peel strength after process exposure. The material shall be subjected to the process specified in 3.1.4.1, after which the peel strength of the material shall be determined as specified in IPC-TM-650, section 2.4.9, method C (except that line width shall be 0.125 inch), and section 2.4.13. A minimum of three 0.125-inch wide lines from the machine direction and three 0.125-inch wide lines from the transverse direction, for each side of the laminate, shall be subjected to test, to determine compliance with the requirements of 3.1.4.1. Failure of the substrate material, that is, Kapton tears or tensile failures at less than 7 pounds per inch of width, shall be considered an acceptable condition.

4.4.4.2 Peel strength after solder immersion. The peel strength of the material after solder immersion shall be determined as specified in IPC-TM-650, sections 2.4.13 and 2.4.9, method A, to verify compliance with the requirements of 3.1.4.2. Failure of the substrate material, that is, Kapton tears or tensile failures at less than 7 pounds per inch of width, shall be considered an acceptable condition.

4.4.5 Workmanship inspection. The material shall be examined for compliance with the workmanship requirements of 3.4.

4.4.6 Inspection of preparation for delivery. Inspection for compliance with the requirements of section 5 shall be performed on packages of item that have been prepared for delivery.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging. Unless otherwise specified in the contract or purchase order (see 6.2), preservation and packaging shall be in accordance with 5.1.1.

5.1.1 Level C preservation and packaging. Preservation and packaging shall be in accordance with the supplier's commercial practices to afford protection from damage during shipment, within the scope of this specification, from the supply source to the first receiving activity.

5.2 Packing. Unless otherwise specified in the contract or purchase order (see 6.2), packing shall be in accordance with 5.2.1.

5.2.1 Level C packing. The material packaged as specified shall be packed in containers of the type, size and kind commonly used for the purpose, in a manner that will ensure acceptance by common carrier and safe delivery at destination. Shipping containers shall be in compliance with the Uniform Freight Classification ratings, rules, and regulations, or the ratings, rules, and regulations for other carriers, as applicable to the mode of transportation.

5.3 Marking. Unless otherwise specified in the contract or purchase order (see 6.2), unit packages, intermediate packages, and exterior shipping containers shall be marked in accordance with MIL-STD-129 (and shall include, but not be limited to, Code Ident, and Part No).

6. NOTES

6.1 Intended use. The material covered by this specification is intended for use in production flexible printed wiring, and it is also intended that the associated copper laminate, and adhesive (when required) will be in accordance with MIS-23659 and MIS-23660.

6.2 Ordering data. Procurement documents should specify the following:

(a) Title, number, and date of issue in effect of this drawing.

(b) Pilot lot inspection, whether required (see 4.2.1).

(c) Pilot lot inspection, (any change in supplier's processes, or relocation of supplier's plant or facilities shall require performance of a new pilot lot inspection) (see 4.2.1).

(d) Periodic conformance inspection, whether required (see 4.2.2).

(e) Responsibility for inspection, if other than that specified (see 4.1.1).

(f) Pilot lot inspection sampling, if other than that specified (see 4.2.1.1).

(g) Action in case of pilot lot inspection failure, if other than that specified (see 4.2.1.2).

(h) Periodic conformance inspection, if other than that specified (see 4.2.2).

(i) Action in case of periodic conformance inspection failure, if other than that specified (see 4.2.2.2).

(j) Quality conformance inspection, if other than that specified (see 4.3).

(k) Applicable level of preservation, packing, packaging and marking, if other than that specified (see 5.1, 5.2, and 5.3).

6.3 Sampling procedures. Sampling procedures shall be as specified in 4.3.2.

6.4 Definitions. The following definitions apply to this drawing.

6.4.1 Inspections. When the term inspection is used herein, it is used as specified in MIL-STD-109.

6.4.2 Verification methods. The following definitions apply to the verification methods specified in table II.

(a) Test. Tests are those inspections which can be made by applying predetermined stimuli to the item under test and observing, measuring, or comparing the responses to ascertain that desired performance has been obtained.

(b) Review of analytical data and design. Review and analysis of engineering data to verify compliance as specified in table I.

(c) Demonstration. Verification of the compatibility of interfaces or actual operation of the equipment, or both.

(d) Examination. Examinations are those inspections which can be made by visual, tactile, or mechanical means to verify that requirements have been met.

6.4.3 Batch. When the term batch is used herein, it is used as specified in MIL-STD-105.

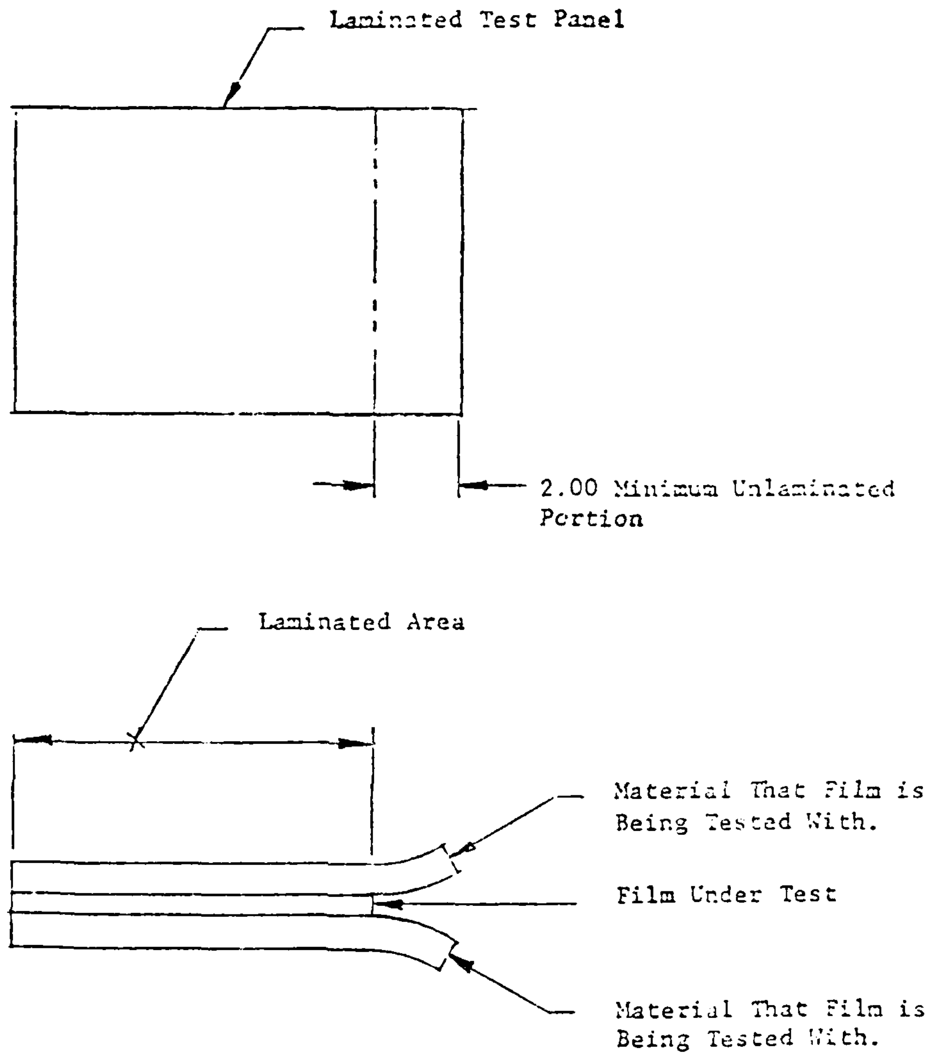
6.5 Suggested source(s) of supply:

DuPont, E.I., DeNemours and Co., Inc.
Fabrics and Finishes Department
85 Mill Plain Road
Fairfield, Ct. 06430

Supplier's Part Number: LF 0200
Supplier's Code Ident: 90056

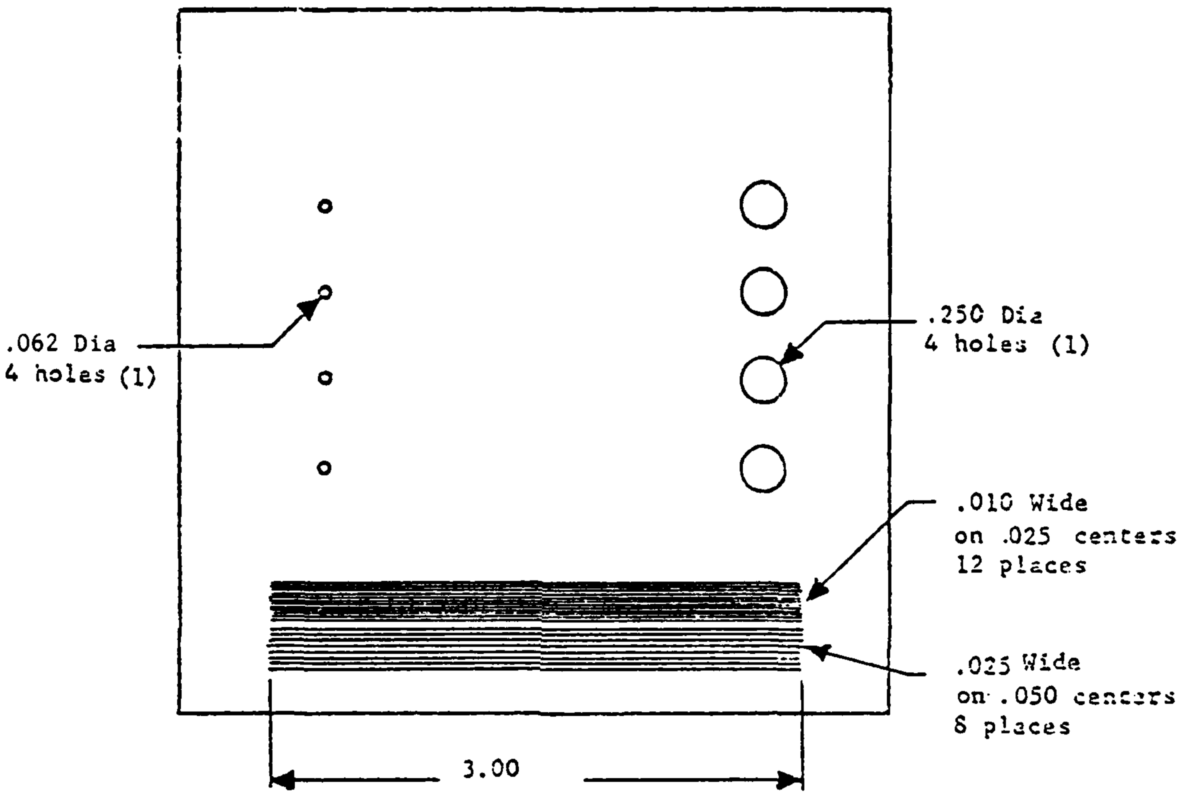
6.6 Concluding page. The last page of this specification includes an asterisk immediately to the right of the page number. The symbol indicates that nothing else follows that page.

Custodian:	Preparing activity:
ARMY-MI	U.S. Army Missile Research and Development Command Redstone Arsenal, Alabama 35809



NOTE: Use like material on both sides of film for each laminated panel, except for the test with plasma treated glass epoxy board. For glass epoxy board peel tests use rolled annealed copper, or polyimide film treated to enhance bondability, for one side of laminated panel.

Figure 1. Peel strength test preparation



(1) Thru insulation sheet only.

Figure 2. Adhesive flow test pattern

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EXHIBIT 52

PRODUCT SPECIFICATION FOR
RIGID-FLEX PRINTED WIRING CABLES

PRODUCTION FABRICATION SPECIFICATION
FOR RIGID-FLEX PRINTED WIRING CABLES

1. SCOPE

1.1 Scope. This specification establishes the requirements for manufacture and acceptance of rigid-flex printed wiring cables.

2. APPLICABLE DOCUMENTS. The following list of documents shall be deemed part of this specification to the extent specified herein.

SPECIFICATIONS

Military

MIL-D-1000	-	Drawing, Engineering and Associated Data
MIL-D-14550	-	Copper Plating (Electro Deposited)
MIL-C-45662	-	Calibration System Requirements

Federal

L-T-90	-	Tape Pressure Sensitive, Adhesive (cellophane and cellulose acetate)

STANDARDS

Federal

FED-STD-102	-	Preservation, Packaging and Packing Levels

Military

MIL-STD-104	-	Sampling Procedures and Tables for Inspection Attributes
MIL-STD-109	-	QUALITY ASSURANCE Terms and Definitions
MIL-STD-129	-	Marking for Shipment and Storage
MIL-STD-202	-	Test Methods for Electronic and Electrical Component Parts
MIL-STD-454	-	Standard General Requirements for Electronic Equipment

DRAWINGS

Engineering Drawing for P/N 3217116

OTHER PUBLICATIONS

American Society for Testing and Materials

ASTM E 53-48
ASTM A 219-58

US Army Missile Command

MIS 23659 Insulating Sheet, Polyimide, Copper Clad
MIS 23660 Insulating Sheet, Polyimide
MIS 23661 Film, Adhesive

N.O.S.C. Contract

M-24-6-874 Thin Polyimide Glass Copper Clad Laminate
M-24-6-885 Immersion Tin Plating of Rigid-Flex Printed Wiring Cables

3. REQUIREMENTS

3.1 Item Definition. A rigid-flex printed wiring cable is a device which provides electrical circuit paths from point to point, usually from one pin type connector to another. In addition the circuit paths are constructed so that they may be bent or flexed for orientation into more than one plane. The flexible circuitry is bonded to a rigid area in successive layers to provide multilayer capability and all circuits with common termination points are connected with plated-through-holes.

In practice, one or more single or double sided flexible printed wiring cables are photoengraved and etched. Insulation sheet is laminated to the outside of the cables and multiple individual cables are laminated to polyimide glass laminate outer stiffeners in the areas of common circuit termination. Holes are drilled in the rigid area, piercing common circuit termination pads, and copper plating is deposited in the hole to provide electrical continuity to all common circuits.

3.2 Characteristics

3.2.1 Performance. Generally, the performance of the rigid-flex cables shall conform to all requirements specified on the engineering drawing for each individual part configuration and those specified in this document unless there is a conflict. In such case, the engineering drawing takes precedence. The following performance requirements apply to rigid-flex printed wiring cables fabricated to this specification.

3.2.1.1 Circuit Continuity. When tested as specified in 4.2.1 there shall be no indication of a broken, cut, or discontinuous circuit path (open circuit) between any two terminals on the same circuit. In addition, the series resistance of each conductor shall be no greater than 1.0 ohm.

3.2.1.2 Current Carrying Capacity. When tested as specified in 4.2.2 there shall be no open circuits in the rigid-flex cable and the temperature rise cannot exceed those requirements specified in Figure 1 of the appendix.

3.2.1.3 Insulation Resistance. When tested as specified in 4.2.3 the insulation resistance between conductors shall not be less than 20 Megohms.

3.2.1.4 Dielectric Withstanding Voltage. When tested as specified in 4.2.4 there shall be no flashover, sparkover, or breakdown.

3.2.1.5 Interconnection Resistance. When tested as specified in 4.2.5, the interconnection resistance from the surface terminal area on one side to the surface terminal area on the other side or through any internal conductor line to a surface terminal area shall not be greater than 0.001 ohm per 0.125 inch of conductor length.

3.2.1.6 Thermal Shock. When tested in accordance with 4.2.6 the circuit continuity, current carrying capacity, and warp and twist characteristics of the cable shall conform to this specification. In addition, the cable shall exhibit no blistering, measling, crazing or delamination.

3.2.1.7 Moisture Resistance. When tested as specified in 4.2.7 the rigid-flex cable insulation resistance, warp and twist, dielectric withstanding voltage, circuit continuity and current carrying capacity characteristics shall conform to this specification. In addition, the cable shall exhibit no blistering, measling, crazing, delamination or corrosion.

3.2.1.8 Warp and Twist, (Rigid Portion Only). When tested as specified in 4.2.8 the maximum allowable warp and twist shall be 1.5 percent. After thermal shock and moisture resistance conditioning, the maximum allowable warp and twist shall be 3.0 percent (noncummulative).

3.2.1.9 Hot Oil Resistance. When tested as specified in 4.2.9 there shall be no degradation of the plated-through-hole or conductive patterns and the cable shall exhibit no blistering, measling or delamination.

3.2.1.10 Bond Strength (Terminal Pull). When subjected to five cycles of soldering and unsoldering as specified in 4.2.10, plated-through-holes on the rigid portion of the cable shall withstand a 10 pound pull force and on the flexible portion a 5 pound pull force without exhibiting cracking or other forms of plated-through-hole degradation. The conductive pattern and laminate shall also show no signs of delamination, blistering or measling and the solder shall wet the entire termination pad and plated-through-hole.

3.2.1.11 Thermal Stress (Solder Float). When tested as specified in 4.2.11 the rigid portion of the cable shall exhibit no measling, fractures, or separation of plating and conductors, blistering or delamination.

3.2.1.12 Flexibility (Flexible portion only). When tested as specified in 4.2.12 the cable shall exhibit no delamination, physical degradation, or electrical discontinuity.

3.2.1.13 Solderability. When the rigid-flex cable is tested as specified in 4.2.13 solder shall wet at least 90 percent of the conductor not covered by insulating material or adhesive.

3.2.1.14 Plating Adhesion. When tested as specified in 4.2.14 there shall be no plating particles or conductor patterns removed from the cable.

3.2.1.15 Machinability. The cable shall be capable of withstanding the required machining operations in all directions without cracking, splitting, delaminating or in any other way exhibiting degradable effects which are in excess of those limits required by this specification.

3.3 Design and Construction

3.3.1 Design. The rigid-flex cable shall be fabricated to all design constraints imposed by the master engineering drawings, parts list, and other documents which invoke this specification for production.

3.3.1.2 The contractor shall furnish one copy of the master engineering drawing which was prepared in accordance with MIL-D-1000 and shows all dimensions and features necessary to produce the subject rigid-flex cable. Detail information such as individual circuit layer identification, circuit configurations, hole sizes, perimeter shape, and material combinations shall also be specified.

3.3.1.1 Precedence. When the requirements of the contract, this specification, or applicable subsidiary specifications, standards, drawings, or other publications are in conflict, the following precedence shall apply:

a) Contract. The contract shall have precedence over any other requirement.
b) Drawing. Except for the contract, the drawing shall have precedence over all referenced documents listed on the drawing.
c) This specification. This specification shall have precedence over all referenced documents except the contract and the drawing. Any deviation from this specification, or from referenced documents where applicable, must have the specific written approval of the procuring activity before adoption.

3.3.2 Standards of Manufacture

3.3.2.1 Materials. Materials used to manufacture rigid-flex printed wiring cables shall meet all requirements contained in the following specifications as demonstrated by conformance to applicable tests and inspections.

Flexible Portion

Copper Clad Kapton Laminate - MIS-23659
Insulation sheet (coverlayer) - MIS-23660

Rigid Portion

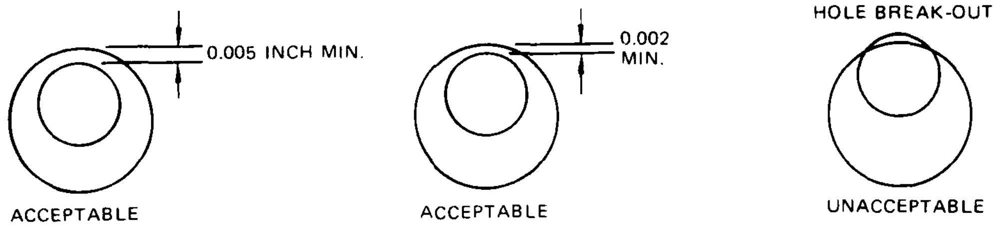
Adhesive Film - MIS-23661
Copper Clad Polyimide-Glass Laminate - M-24-6-874

3.3.2.2 Repair. Rigid-flex cables shall not be repaired unless specifically approved by the procuring activity.

3.3.2.3 Layer to Layer Registration, (Rigid Portion or Individual Flexible Cables). Unless otherwise approved by the procuring activity misregistration of conductive layers shall not exceed 0.014 inch as measured in 4.2.15.

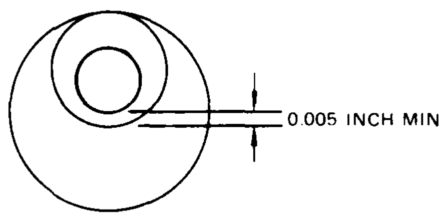
3.3.2.4 Hole Locations. The accuracy of the resulting hole pattern on the rigid-flex cable shall be such that all centers are located within 0.005 inch radius of the true position indicated by the grid location or dimensional location.

Terminal or Feed Through Pad Hole Location. The minimum annular ring of the pad surrounding a hole shall be 0.005 inch for external conductor layers and the hole shall not break out of internal layers.



EXTERNAL PAD INTERNAL PAD

Access Hole in Insulation Sheet (Coverlayer). The edge of the access hole on the datum side of the cable shall be no closer than 0.005 inch to the edge of the hole through the terminal area. The edge of the access hole on the nondatum side shall not overlap the terminal hole.



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DATUM SIDE

3.3.2.5 Holes. Holes shall be drilled using operating parameters which produce a clean cut, with no visible damage to hole walls, laminate, or inner conductive layers. There shall also be no burrs which prevent minimum plated-through-hole diameters from being achieved.

3.3.2.6 Drill Smear Removal. The process used to remove residues from drilled holes which are to be plated through shall completely remove all nonconductive material from inner circuit layer interfaces and the amount of etch-back produced shall not exceed 0.002 inch. In addition, the overall hole wall profile shall be such that it is compatible with the copper plating process and produces a uniform void free, crack free, copper plated-through-hole.

3.3.2.7 Plating. Plating shall be deposited as specified by individual engineering drawings. In general, the one ounce clad copper for the rigid and flexible circuitry is plated to two ounces while achieving the plated-through-holes. Plated-through-holes are achieved using both an electroless process and an electrolytic process.

Electroless Copper Plating. An electroless copper deposition system shall be used as a preliminary process for providing the conductive layer over nonconductive materials for subsequent electro deposition of plated-through-holes.

Electrolytic Copper Plating. All electrolytically deposited copper plating shall be performed in accordance with MIL-C-14550 and shall have a minimum purity of 99.5 percent as determined by ASTM E53-48. Unless otherwise specified, a 0.001 inch minimum plating thickness shall be deposited in plated-through-holes and on conductor surfaces. This shall be verified by microsectioning as specified in 4.2.15.

3.3.2.8 Plated-Through-Holes

Flexible Portion, (Two Sided Cable). When examined as specified in 4.2.15 the following characteristics shall be observed in both a verticle and horizontal cross section.

1. The plating shall be continuous through the hole.
2. The plating shall be free from cracks, pinholes, and voids and the hole shall contain no contamination, photo resist, etc.
3. Nodules, burrs, or annular ridges shall not reduce the hole diameter below minimum requirements specified on detail drawings.
4. The minimum plating thickness in the holes shall be 0.001 inch unless otherwise specified on control drawings.

Rigid Portion, (Multilayer). When a verticle cross section is examined, as specified in 4.2.15, all of the characteristics specified for the flexible portion apply. In addition, those shown below shall also be observed.

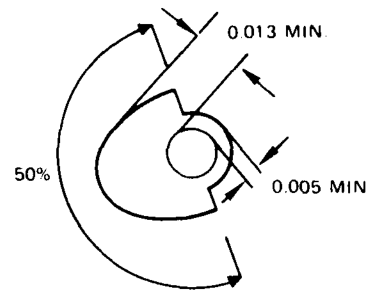
1. There shall be no separation of inner circuit layers from the plated-through-hole.
2. Layer to layer registration shall not exceed 0.014 inch.
3. No hole breakout is permitted in inner conductor layers (3.3.2.4).

3.3.2.9 Burrs. Burrs formed around the periphery of counterboard terminal area clearance holes, or around the periphery of drilled holes shall not exceed 0.015 inch.

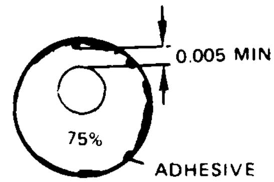
3.3.2.10 Terminal Areas (Pads)

Damage to Pads. Damage to the terminal pad such as nicks, tears, and over-etching shall not reduce the area more than 0.013 inches around at least 50% of the hole periphery with at least 0.005 inch of pad around the remainder of the periphery.

Adhesive on Pad. Extruded adhesive on the datum side of terminal areas can extend to within 0.005 inch of the terminal hole providing at least 75% of the pad is free of adhesive. Extruded adhesive on the nondatum side of the terminal areas may be coincident with the edge of the terminal hole, but shall not extend into the hole.



MAXIMUM DAMAGE
DAMAGE TO PADS



ADHESIVE ON PAD

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3.3.2.11 Conductive Paths. Conductive paths shall be as specified below.

Width. The conductor path width shall be as follows:

All conductor paths shall have a minimum width equal to 70 percent of the reduced-to-size (RTS) master pattern (provided that the narrowest path on the completed part is no less than 0.009 inch).

Scratches and nicks in the edge of conductors shall not reduce the path width beyond limits specified in Table 1.

Table 1. Allowable Scratches and Nicks

Length of nick (inch)	Conductor path width (inch) finished part 1/									
	Up to 0.020	0.030	0.040	0.050	0.060	0.070	0.080	0.090	0.100	Over 0.100
	Minimum remaining path width									
Up to 0.10	0.009	0.012	0.020	0.025	0.030	0.035	0.040	0.045	0.050	50%
0.10 to 0.25	0.009	0.012	0.025	0.030	0.036	0.042	0.048	0.054	0.060	60%
Over 0.025	0.009	0.015	0.028	0.035	0.042	0.049	0.056	0.063	0.070	70%

1/ When a conductor path width does not exactly match the value given in a column heading, use the next larger value.

The total length of all nicks and scratches in any conductor path shall not be more than 10 percent of total length of that conductor path.

Grooves or Scratches. Grooves or scratches shall meet the following requirements. Grooves or scratches which partially extend across a conductor shall be treated as nicks.

Grooves. Grooves (even where conductive foil remains at the bottom of the groove) shall not exist across the width of circuit paths or pads.

Scratches. Scratches that extend across the width of circuit paths or pads shall be visible only by refracted light.

Ground Planes and Shields. Ground planes or shielded layers shall not have pits, voids, scratches, or irregularly etched edges that exceed the following:

The conductive-surface area shown in drawings invoking this specification shall not be reduced by more than 0.030 inch in width, but may in no case be less than 0.009 inch wide.

Voids shall not exceed an area of 0.10 square inch.

Grooves and scratches (except scratches visible only by refracted light) in the conductor are considered to be through the conductor, and shall not extend more than 90 percent across the conductive plane.

Spacing. The spacing of conductive paths shall be as follows:

(a) Conductor-to-conductor (same surface): 0.009 inch, minimum.
(b) Conductor to part edge: 0.015 inch, minimum.
(c) Conductor to access hole: 0.015 inch, minimum.

3.3.2.12 Inclusions. Inclusions shall conform to the following requirements:

Metallic inclusions contacting a conductor shall maintain aluminum conductor-to-conductor clearance of 0.009 inch.

Metallic inclusions shall not extend to within 0.015 inch of the edge of the part, if the inclusion is also within 0.010 inch of a conductor.

The area of any metallic inclusion shall be no greater than 0.05 square inch.

Nonmetallic inclusions contacting or within 0.010 inch of two or more nonrelated conductors shall not result in an insulation resistance between conductors of less than 20 megohms, at 500 (plus or minus 50) vdc.

Metallic inclusions which cross nonrelated conductors shall be on the opposite side of the insulation sheet from the conductors.

3.3.2.13 Cable Outline. The cable outline shall meet the requirements specified below:

Edges. The cable edges shall not have any tears or sharp notches. Irregularities occurring along the cable edge shall not exceed a total variation of 0.030 inch, and no indentation shall have less than a 0.020 inch radius or be within 0.010 inch of a conductor.

Inside Corners. Unless otherwise specified on individual drawings invoking this specification, inside corner radii shall be 0.08 (plus or minus 0.02) inch regardless of the pictorial representation. Radii which are not tangent to either intersecting edge shall have a continuous inside corner.

Outside Corners. Unless otherwise specified on individual drawings invoking this specification, outside corner trim radius shall be no greater than 0.10 inch, regardless of pictorial representation.

Perimeter Dimensions. The perimeter on cables shall be acceptable anywhere within the envelope established by the minimum and maximum dimensions on the drawing. Tolerances on individual features such as angles, radii, or intersecting points may be exceeded providing the total periphery remains within this envelope, and the minimum inside corner radii and the conductor-to-edge-of-part distances are maintained.

3.3.2.14 Bond of Copper to Base Material. Conductive patterns shall not be lifted from the base material in either the rigid area or the flexible area.

3.3.2.15 Laminate Bond in Rigid Area. Delamination in the rigid portion of the cable is not permitted; however, a halo pattern around holes which are used only for mechanical attachment is permitted providing it does not exceed 0.010 inch from the hole edge.

3.3.2.16 Bond of Insulation Sheet (Coverlayer). Delamination of the coverlayer is permitted only as specified below:

Delamination from a termination area shall not extend to within 0.030 inch of the cable edge or within 0.025 inch of an adjacent nonrelated conductor. Delaminations of this type shall not be larger than 0.250 square inches.

Delamination in areas other than termination areas shall not be larger than 0.250 square inches nor closer than 0.050 inch (otherwise it will be considered a single delamination). If the delamination extends between conductors it shall not be closer than 0.050 inch to a hole, cut out, or perimeter edge.

Delamination at edges (cutouts, holes, or perimeter). The delamination shall not occur within 0.050 inch from a conductor. Single delaminations cannot exceed 1 inch in length or depth. Total delaminations cannot exceed 20 percent of the perimeter length.

Delamination may occur on an outside corner of the printed cable when it does not exceed 0.05 inch in any direction. Cables may have corner delamination between 0.05 and 0.50 inch provided the delamination area is cut off. Not more than 25 percent of the length shall be removed along any single, straight portion of cables. The edge distance to any internal hole or cutout shall be at least 0.10 inch.

3.3.2.17 Scratches in the Insulation Sheet (Coverlayer). Coverlayer scratches shall be visible only by refracted light.

3.3.2.18 Identification and Marking. Identification and marking shall be in accordance with the applicable cable drawings and the following shall apply:

Markings which are etched as part of the conductive layer(s) may not be duplicated in ink, although they may be replaced with ink where necessary.

Conductive markings (etched) shall not reduce the spacing below the minimum specified.

Serial numbers shall be as specified in the contract or purchase order.

Manufacturer's symbol, manufacturing date and serial numbers shall not overlap any exposed conductive paths or termination areas.

Inks used for marking shall be permanent, compatible with base materials, and in no case affect cable performance.

Letters and numbers shall be legible after all tests.

3.3.3 Workmanship

3.3.3.1 General Rigid-Flex Workmanship. The cable shall be uniform in quality and free from adhesive smears, deleterious nodules, dirt, corrosion, corrosive products, salt, grease, fingerprints, foreign matter, blisters, resin starved areas, voids and any other defect that will affect life, serviceability or appearance.

3.3.3.2 Those deviations of quality characteristics from nominal shall meet the requirements specified in 3.3.2 (standards of manufacture).

3.3.3.3 In addition those applicable requirements specified in MIL-STD-454 Section 9 apply.

3.4 Preproduction Sample. (First Article.) Unless otherwise specified in the contract or purchase order, a preproduction sample shall be manufactured using the same methods, processes, and procedures proposed for the production of deliverable rigid-flex printed wiring cables. These rigid-flex cables shall be of the same configuration and construction as those intended to be fabricated for delivery and shall be inspected to those requirements specified on the engineering drawings and Section 3 of the specification. Further, production of the cables prior to approval of the preproduction sample shall be at the suppliers risk. No design changes shall be made after acceptance of the preproduction sample without approval of the procuring activity. Unless otherwise specified in the contract or purchase orders, any design change shall require the submittal of a new preproduction sample.

Table 2. Preproduction Sample (First Article) Inspection

Group A Inspection

Examination or Test	Requirement Para.	Method Para.	Quality Conformance Test Circuit
Visual and Dimensional			
Material	3.3.2.1	4.2.1	All
Plating	3.3.2.6	4.2.16	All
Plated through hole	3.3.2.7	4.2.16	F
Dimensions	Engr. DWG &	4.2.1.16	
	Sec. 3.3.2	4.2.1	All
Machineability	3.2.1.14	4.2.1	All
Repair	3.3.2.2	4.2.1	All
Workmanship	3.3.3	4.2.1	All
Plating Adhesion	3.2.1.14	4.2.15	C
Bond Strength (terminal pull)	3.2.1.10	4.2.11	F
Warp and Twist	3.2.1.8	4.2.9	All
Hot Oil Resistance	3.2.1.9	4.2.10	E
Thermal Stress	3.2.1.11	4.2.12	D/G
Solderability	3.2.1.13	4.2.14	Any
Circuit Continuity	3.2.1.1	4.2.2	D/G
Current Carrying Capacity	3.2.1.2	4.2.3	D/G
Insulation Resistance	3.2.1.3	4.2.4	E
Dielectric Withstanding Voltage	3.2.1.4	4.2.5	E
Interconnection Resistance	3.2.1.5	4.2.6	D/G
Thermal Shock	3.2.1.6	4.2.7	D/G
Circuit Continuity	3.2.1.1	4.2.2	D/G
Current Carrying Capacity	3.2.1.2	4.2.3	D/G
Warp and Twist	3.2.1.8	4.2.9	All
Moisture Resistance	3.2.1.7	4.2.8	
Insulation Resistance	3.2.1.3	4.2.4	E
Dielectric Withstanding Voltage	3.2.1.5	4.2.6	E
Circuit Continuity	3.2.1.1	4.2.2	D/G
Current Carrying Capacity	3.2.1.2	4.2.3	D/G
Warp and Twist	3.2.1.9	4.2.9	All
Flexibility	3.2.1.12	4.2.13	Cable
Copper Purity (Optional)	3.3.2.6	3.3.2.6	Any

NOTE: All indicates entire cable or all coupons as applicable. The quality conformance test circuit is defined in 4.1.3.

Table 3. Periodic Lot Inspection (6 Month Interval)

Group B Inspection

Examination or Test	Requirement Para.	Method Para.	Quality Conformance Test Circuit
Bond Strength (Terminal Pull)	3.2.1.10	4.2.11	C
Thermal Stress	3.2.1.11	4.2.12	D/G
Solderability	3.2.1.13	4.2.14	Any
Thermal Shock	3.2.1.6	4.2.7	D/G
Circuit Continuity	3.2.1.1	4.2.2	D/G
Current Carrying Capacity	3.2.1.2	4.2.3	D/G
Warp and Twist	3.2.1.8	4.2.9	All
Moisture Resistance	3.2.1.7	4.2.8	
Insulation Resistance	3.2.1.3	4.2.4	E
Dielectric Withstanding Voltage	3.2.1.4	4.2.5	E
Circuit Continuity	3.2.1.1	4.2.2	D/G
Current Carrying Capacity	3.2.1.2	4.2.3	D/G
Warp and Twist	3.2.1.9	4.2.9	All
Interconnection Resistance	3.2.1.5	4.2.6	D/G
Flexibility	3.2.1.12	4.2.13	Cable
Current Carrying Capacity	3.2.1.2	4.2.3	D/G
Dielectric Withstanding Voltage	3.2.1.4	4.2.5	E

NOTE: All indicates entire cable or all coupons as applicable. The quality conformance test circuit is defined in 4.1.3.

Table 4. Quality Conformance Lot Inspection (Each Production Lot)

Group C

Examination or Test	Requirement Para.	Method Para.	AQL INS Level	Quality Conformance Test Circuit
Visual and Dimensional				
Material	3.3.2.1	4.2.16	100%	All
Plating	3.3.2.6	4.2.15	100%	All
Plated-through-hole	3.3.2.7	4.2.15	100%	A/F
Dimensions	Engr. Dwg & Sec. 3.3.2	4.2.1.16	AQL 2.5	All
Machineability	3.2.1.14	4.2.1.16	100%	All
Repair	3.3.2.2	4.2.1.16	100%	
Workmanship	3.3.3	4.2.1.16	100%	All
Plating Adhesion			AQL 2.5	C
Warp and Twist			AQL 2.5	All
Hot Oil Resistance			AQL 2.5	E
Circuit Continuity			100%	D/G
Insulation Resistance			100%	E

NOTE: All indicates entire cable or all coupons as applicable. The quality conformance test circuit is defined in 4.1.3.

4. QUALITY ASSURANCE PROVISIONS

4.1 General. This section establishes the requirements for verifying cable conformance to the requirements of section 3 and the engineering drawing by test, analysis, demonstration, or examination. The quality assurance provisions shall consist of the following classification of inspections and shall be as specified in Tables 2, 3 and 4:

Class A Preproduction sample (first article) inspection
Class B Periodic conformance inspection
Class C Quality conformance (lot) inspection

4.1.1 Responsibility for Inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performances of all inspection requirements as specified herein. Except as otherweise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

4.1.1.1 Inspection Equipment, Facilities, and Conditions. Inspection equipment and facilities shall be of adequate quality and quantity to permit performance of the required examinations and tests. Unless otherwise specified, all examinations and tests shall be performed within the following ranges of ambient temperature, humidity, and pressure:

(a) Temperature: Plus 18 degrees to plus 35 degrees Centigrade (plus 65 degrees to plus 95 degrees Fahrenheit).
(b) Relative humidity: Up to 95 percent.
(c) Barometric pressure: Local average plus or minus 2 inches of mercury.

4.1.1.2 Test Equipment Error. Equipment used to measure parameters shall introduce no overall errors greater than 10 percent of the tolerance on the parameter, or in the case of a single limit tolerance, the test equipment error shall be applied to the specific parameter in such a manner as to assure that the specified parameter is being met. Test equipment calibration shall comply with the requirements of MIL-C-45662.

4.1.2 Special Tests and Examinations

4.1.2.1 Preproduction Sample (First Article) Inspection

4.1.2.1 Preproduction Sample Inspection. This inspection shall consist of the inspections specified in Table 2 and shall consist of verification of the requirements of Section 3 and engineering drawing by the methods so specified. Verification of the requirements shall be performed in a test sequence acceptable to the procuring activity. This inspection shall be performed on cables taken from at least the first 10 cables produced that have satisfactorily passed the quality conformance inspection of Table 4 and subjected to the sampling specified in 4.1.2.1.1.

4.1.2.1.1 Preproduction sample inspection sampling. Unless otherwise specified in the contract or purchase order, the pilot lot test items shall consist of six cables randomly selected from the pilot lot and subjected to the specified inspections of Table 2. In addition, each test item in this sample group shall be inspected for compliance with all the requirements specified on the applicable drawing, not merely those for which inspections are specified herein.

4.1.2.1.2 Action in case of failure. Failure of any cable to meet one or more of the requirements specified in Table 2 shall constitute a defective. If defectives are found during any inspection the entire preproduction sample shall be rejected. The supplier shall then take corrective action that is acceptable to the procuring activity to correct the cause(s) for failure. Unless otherwise specified in the contract or purchase order, a subsequent production lot of cables shall not be considered for acceptance until the preproduction sample cables subjected to the inspections of Table 2 have satisfactorily passed the inspections following any corrective action.

4.1.2.2 Periodic conformance inspection. The periodic conformance inspections shall consist of the inspections specified in Table 3 and shall consist of verification of the requirements specified by the methods noted therein. Verification of the requirements shall be performed in a test sequence acceptable to the procuring activity. Unless otherwise specified in the contract or purchase order, the periodic conformance inspection shall be performed on test items selected in accordance with 4.1.2.2.1.

4.1.2.2.1 Periodic conformance inspection sampling. The periodic conformance test items shall consist of five cables randomly selected from the cables produced every 6 months or from every 5000 cables, whichever occurs first, which have satisfactorily passed the quality conformance inspections of 4.2 specified in Table 3. The five cables shall be subjected to the periodic conformance tests specified in Table 3.

4.1.2.2.2 Action in case of periodic conformance inspection failure. Failure of any test item to meet one or more of the requirements specified for periodic conformance inspection shall constitute a defective. If defectives are found, the supplier shall take corrective action acceptable to the procuring activity to correct the cause(s) for failure. Unless otherwise specified in the contract or purchase order, subsequent production cables shall not be considered for acceptance until all the test items subjected to the inspections of 4.1.2.2 have satisfactorily passed the inspections following any corrective action.

4.1.2.3 Quality conformance inspection. Quality conformance inspection shall consist of the inspections specified in Table 4 for verification of the requirements by the methods noted herein. Unless otherwise specified in the contract or purchase order, the inspections may be performed in any sequence acceptable to the procuring activity. The classification of characteristics specified in Section 4.3 shall be as follows:

(a) Critical characteristics: 001-099
(b) Major characteristics: 101-199
(c) Minor characteristics: 201-299

4.1.2.3.1 Quality conformance inspection lot. The quality conformance inspection lot shall consist of all cables which are manufactured in continuous production under uniform conditions and are offered for inspection at any one time. Inspection lots containing more than one circuit pattern shall not exceed 150 cables.

4.1.2.3.2 Quality conformance inspection sampling. The quality conformance inspection shall be performed on a 100-percent basis or sample inspected to the acceptable quality level (AQL) specified in Table 4 in accordance with MIL-STD-105. If two or more circuit patterns are presented for inspection at the same time the AQL sample shall consist of equal numbers of each circuit pattern, except that for inspection lots of 25 cables or less, only the most complex circuit pattern need be tested. For inspection lots consisting of more than 25 cables at least one specimen of each circuit pattern shall be tested.

4.1.2.3.3 Inspection, AQL. The requirements of MIL-STD-105 shall apply for acceptance and rejection.

4.1.2.3.4 Inspection, 100 percent. Where a 100-percent inspection is specified, only defective cables shall be rejected.

4.1.3 Quality Conformance Test Circuit (Test Coupon). And test circuit pattern corresponding with the configuration and dimensions shown in Figure 2 of the appendix shall be incorporated into every panel from which a rigid-flex is manufactured. In addition, each printed wiring detail cable which goes into the subject rigid-flex cable shall be manufactured with a test coupon of the configuration shown in Figure 3 of the appendix. The test circuits shall be provided to demonstrate conformance of all characteristics in Tables 2, 3 or 4. Each table specifies the specific area of the test circuit to be used for its corresponding test or inspection.

4.2 Quality Conformance Inspections.

4.2.1 Circuit Continuity. A current shall be passed through the test circuit or actual circuit by applying electrodes to the end terminations of the conductor or group of conductors. The current passed through the conductors shall not exceed the value specified for the smallest conductor in the circuit as shown in Figure 1 of the appendix.

4.2.2 Current Carrying Capacity. The cable shall be tested and open circuits with currents as specified in Figure 1 of the appendix. The temperature rise of the circuit shall not be higher than specified in the diagram for the given current.

4.2.3 Insulation Resistance Test. The insulation resistance shall be tested as follows:

(a) Measure the insulation resistance in accordance with MIL-STD-202, method 302, condition B, with a test potential applied for at least 0.1 second.
(b) The cable insulation resistance between conductors shall comply with the requirement of 3.2.1.3.

4.2.4 Dielectric Withstanding Voltage. The dielectric withstanding voltage shall be applied between all common portions of each conductor pattern and all adjacent common portions of each conductor pattern. The voltage shall be applied between conductor patterns of each layer and the electrically isolated pattern of each adjacent layer.

Quality conformance test circuits. Specified test circuits shall be tested with a potential of 1,000 volts dc for a period of 30 seconds in accordance with method 301 of MIL-STD-202.

First article and production boards. First article and production boards shall be tested at a potential of 500 volts dc in accordance with method 301 of MIL-STD-202. For manual testing, the voltage shall be applied for 5 seconds minimum; for automatic testing, the voltage shall be applied for a time period compatible with the equipment used.

4.2.5 Interconnection resistance (see 3.18). Using an instrument capable of reading resistance less than 0.005 ohm, measure the resistance between each pair of terminals in quality conformance test circuit D or G. Solder leads in the terminal holes in order to assure adequate contact with the hole under test.

4.2.6 Thermal Shock. The thermal shock test shall be performed in accordance with MIL-STD-202, Method 107D, condition A and the test circuit or cable shall be examined and tested for conformance to requirements in 3.2.1.6.

4.2.7 Moisture Resistance. The moisture resistance test shall be performed in accordance with method 106 of MIL-STD-202, using the first six steps only for 10 cycles. A polarizing voltage of 100 volts dc shall be applied. Following step 6 of the tenth cycle, the specimens shall be removed from the humidity chamber and immediately blown dry at 25° ± 5°C and evaluated.

4.2.8 Warp and Twist. The cable shall be placed unrestrained on a flat horizontal surface with the convex surface of the panel upward. The maximum vertical displacement (the vertical distance from the horizontal surface to the maximum height of the concave surface) shall then be determined by taking the measurement and subtracting the thickness of the board if it is included in the height measurement. The adjusted height divided by the length of the longest side and multiplied by 100 shall be considered the percent warp or twist.

4.2.9 Hot Oil Resistance. The cable shall be dried in a 104°C oven for two hours, then cooled to room temperature in a desiccator. The cable shall be removed from the desiccator and immediately immersed in hot oil or wax at 260° + 5.56°C for a period of 20 ± 2 seconds.

4.2.10 Bond Strength. The cable shall be dried in a recirculating oven at 104°C for two hours and cooled to room temperature in a desiccator. Copper or copper alloy wires of compatible size shall be inserted into the holes in selected terminal areas and soldered to terminal areas by machine or hand, as applicable. The wires shall not be clinched. Subject wires to five

cycles of unsoldering and soldering by hand after the initial machine or hand soldering. During the five cycles the wires shall be completely removed during each unsoldering operation and replaced during each soldering operation. A 60-watt conventional soldering iron operating at a reduced voltage sufficient to produce a tip temperature of 232° to 260°C shall be used for the unsoldering and soldering operation. The iron shall be applied to the leads, not the foil, and shall be applied only as long as is necessary to perform the unsoldering or soldering operation. Following the fifth cycle, the cable shall then be clamped in the jaws of the bond tester. A pull at the rate of 2-inches per minute shall be applied to the wire (on the terminal area side, in the case of a bare hole). The pull shall be applied until the specified load is reached. For terminals in the rigid area apply a 10-pound force and for terminals on the flexible area apply a 5-pound force. After meeting the requirements of 3.2.1.10 and tested as described above, the holes shall be microsectioned and examined.

4.2.11 Thermal stress (solder float) (see 3.19). The board shall be conditioned at 121° to 149°C for one hour. The board shall then be floated in a solder bath (Sn63 ± 5%, maintained at 288° ± 5.56°C) for a period of 10 seconds, then microsectioned and examined in accordance with 4.2.15.

4.2.12 Flexibility

Folding (see 3.15.1). Unless otherwise specified on the master drawing, the same point on the flexible printed wiring shall be subjected to 5 cycles (10 folds) of folding 180 degrees in each direction around a mandrel. The radius of the mandrel shall be no greater than 12 times nor less than 10 times the total thickness of the flexible printed wiring.

Endurance (see 3.15.2). Where applicable, the flexible printed wiring shall be subjected to a flexibility endurance test as specified on the master drawing. In such cases the master drawing shall specify the number of flexing cycles, the flexing rate, and points of applications of the flexing.

4.2.13 Solderability (see 3.13). The solderability test procedure shall be as follows:

(a) Dry specimen in a vacuum oven at 165°F and 25 in. Hg for 2 hours.
(b) Flux with solution of 20-percent white resin and 80-percent isopropyl alcohol (weight percentages) by brushing or dipping.
(c) Allow to drain on edge until alcohol has evaporated.
(d) Place specimens in suitable fixture (see Figure 3), foil side down, just under surface of molten solder (Sn63 or Sn60, type S conforming to QQ-S-571[1/]) at 232° ± 5°C for 5 seconds. Specimens should be agitated laterally during immersion.
(e) Remove specimens from solder bath, tap edge to remove excess solder and allow to cool to room temperature.
(f) Visually examine the circuit area for proper solder wetting and any evidence of physical damage.

[1/]All dross should be removed from the solder surface prior to immersion of sample.

4.2.14 Plating adhesion (see 3.7). A strip of pressure sensitive cellophane tape conforming to type I, class A to L-T-90, 1/2-inch wide and 2-inches long shall be placed across the surface of the conductor pattern and pressed firmly to the conductors eliminating air bubbles. A tab shall be left for pulling. The tape shall be pulled with a snap pull at an angle of approximately 90 degrees to the board. Tape shall be applied to, and removed from, three different locations on each board tested. When edge board contacts are part of the pattern, at least one pull must be on the contacts. Fresh tape shall be used for each pull. If overhang metal breaks off (slivers) and adheres to the tape, it is evidence of overhang, but not a plating adhesion failure.

4.2.15 Plated-through-hole examination. Plating examinations shall be accomplished by using methods in ASTM A219-58.

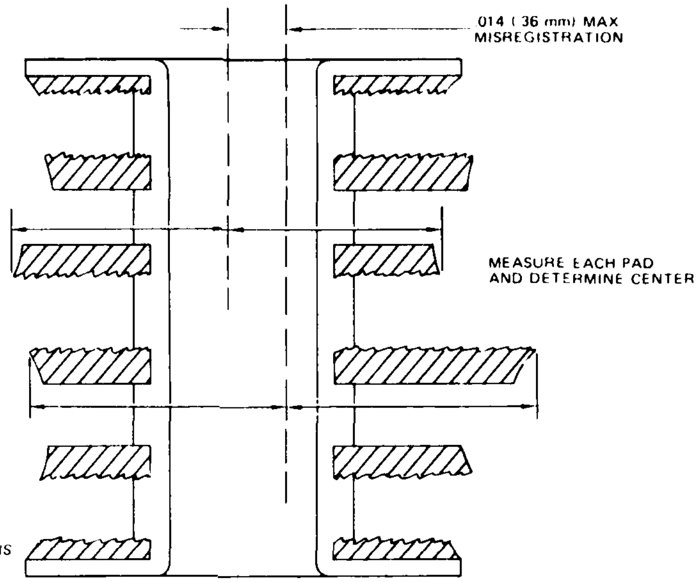
Vertical (see 3.5 and 3.5.1). Plated-through-holes shall be microsectioned in the vertical plane at the center of the hole and examined for quality of plating at 50 to 100 magnifications. Plating thickness shall be measured at 350X minimum. Each side of the hole shall be viewed independently. A minimum of one microsection shall be made for each panel produced.

Horizontal (see 3.5 and 3.5.2). Plated-through-holes shall be microsectioned in the annular plane midway between the internal conductors nearest the center of the total board thickness and shall be examined for quality of plating at 50 to 100X minimum. Plating thickness shall be measured at 350X minimum.

Measurements. Measurements shall be reported as the average of three determinations per hole. Isolated thick or thin sections shall not be used for averaging.

Layer to layer registration (see 3.6.1.3). Layer to layer registration shall be measured at 100 to 400 magnifications after vertical microsectioning of two plated-through-holes as detailed on 4.7.1.1. One plated-through-hole shall be vertically cross sectioned parallel to the board length, and one vertically cross sectioned perpendicular to the board length. These microsections shall be evaluated by computing the difference of centerlines of terminal pads shifted to extreme positions (see sketch below).

4.2.16 Visual and Dimensional Examination. The cables shall be visually examined and measured to assure conformance to all applicable requirements in Section 3 of this specification and of the master engineering drawing. Magnification to 10X may be used. Characteristics such as design, construction, physical dimensions, machineability, repair, marking, and workmanship shall be examined.



Layer to layer registration.

4.3 Classification of Characteristics

Characteristic Code Number	Major Characteristics
101	Circuit continuity (Para 3.2.1.1)
102	Current carrying capacity (Para 3.2.1.2)
103	Insulation Resistance (Para 3.2.1.3)
104	Dielectric withstanding voltage (Para 3.2.1.4)
105	Interconnection Resistance (Para 3.2.1.5)
106	Thermal shock (Para 3.2.1.6)
107	Moisture Resistance (Para 3.2.1.7)
108	Warp and twist (Para 3.2.1.8)
109	Hot oil resistance (Para 3.2.1.9)
110	Bond strength (terminal pull) (Para 3.2.1.10)
111	Thermal stress (solder float) (Para 3.2.1.11)
112	Flexibility (Para 3.2.1.12)
113	Solderability (Para 3.2.1.13)
114	Plating Adhesion (Para 3.2.1.14)
115	Machineability (Para 3.2.1.14)
116	Materials (Para 3.3.2.1)
117	Hole locations terminal holes (Para 3.3.2.4)
118	Holes (Para 3.3.2.5)
119	Drill smear removal (Para 3.3.2.6)
120	Plating (Para 3.3.2.7)
121	Plated through holes (Para 3.3.2.8)
122	Burrs (Para 3.3.2.9)
123	Terminal areas (Para 3.3.2.10)
124	Conductor paths (Para 3.3.2.11)

Characteristic Code Number	Major Characteristics
125	Inclusions (Para 3.3.2.12)
126	Cable outline (Para 3.3.2.13)
127	Bond of copper to base material (Para 3.3.2.14)
128	Laminate bond in rigid area (Para 3.3.2.15)
129	Bond of Insulation sheet (coverlayer) (Para 3.3.2.16)

Characteristic Code Number	Minor Characteristics
201	Layer to layer registration (Para 3.3.2.3)
202	Hole locations, access holes (Para 3.3.2.4)
203	Scratches in insulation sheet (Para 3.3.2.17)
204	Identification and marking (Para 3.3.2.18)
205	Workmanship (Para 3.3.3)

5. PREPARATION FOR DELIVERY

5.1 General. Unless otherwise specified in the contract or purchase order, all rigid-flex cables shall be packaged according to FED-STD-102 per the level specified in 5.2.

5.2 Specific Requirements. Level C is required for packaging rigid-flex printed wiring cables to assure that they have been cleaned, dried, and individually packaged in a manner that will afford adequate protection against corrosion, deterioration, and physical damage during shipment from supply source to the first receiving activity for immediate use (vendor to user).

5.2.1 Cleaning and drying prior to packaging shall be performed as part of the production process specified in process specification M-24-6-885.

5.2.2 Packing. The cable packages as specified shall be packed in containers of the type, size and kind commonly used for the purpose, in a manner that will ensure acceptance by common carrier and safe delivery at destination. Shipping containers shall be in compliance with the Union Freight Classification Ratings, Rules, and Regulations, or the ratings, rules, and regulations for other carriers, as applicable to the mode of transportation.

5.2.3 Marking. Unless otherwise specified in the contract or purchase order unit packages, intermediate packages, and exterior shipping containers shall be marked in accordance with MIL-STD-129.

6. NOTES

6.1 Intended Use. Rigid-flex cables are intended primarily for use in electronic and electrical equipment or weapon systems which require high density point to point wiring where space and weight is limited and where compact packaging is desirable.

6.2 Ordering Data

a) Title, number, and date of this specification
b) Title, number, and date of the applicable master drawings
c) Master drawing conflicts
d) Type of inspections: production sample, periodic, quality conformance (Lot)
e) Location and responsibility for inspection
f) Marking instruction if not covered by this specification
g) Packaging instructions if not covered by this specification
h) Allowable production process changes
i) Allowable deviations to engineering drawings

6.3 Preproduction Sample (first article). Information pertaining to first article inspection of products covered by this specification should be obtained from the procuring activity for the specific contracts involved.

6.4 Oral Statement. No oral statement by any person or persons will be allowed in any manner or degree to modify or otherwise affect the requirements of any part of this specification, or any specification, standard, publication, drawing or document required herein.

6.5 Definitions. The following definitions apply to this specification when the terms defined are used herein.

a) Base. The base is the insulating support for printed wiring or printed-circuits.
b) Clearance holes. Holes perforated in each layer or through the insulation cover, opposite the component side, to provide access to terminal areas.
c) Conductive paths. A conductive path is a single conductive line forming an electrical connection between terminal areas.
d) Cover layer (coverlay). The cover layer is the outer layers of insulating material over the conductors.
e) Datum side. Datum side is that side of a cable from which all dimensions for a particular area of a cable are taken. The datum may vary from side to side on any given cable.
f) Delamination. Delamination is the separation of printed harness material within the laminations.
g) Groove. A groove is a localized defect or imperfection of a conductor caused by etching the surface partially through.
h) Inclusions. Inclusions are foreign particles, conductive or nonconductive, laminated into a cable.
i) Interfacial connection. An interfacial connection is an electrical connection between conductive patterns on opposite sides of the base.

j) Nick. A nick is a void at the edge of a conductor on a cable.

k) Nodule. A nodule is a protuberance of plated-on material on a conductor or in a plated-through-hole.

l) Nonwetting. Nonwetting is a condition whereby a surface has contacted molten solder, but has had no solder adhere to it.

m) Plated-through-hole. A plated-through-hole is an interfacial or interlayer, connection formed by deposition of conductive material on the sides of a hole through the base and on the terminal areas.

n) Scratch. A removal of the material along a path that is relatively much greater in one dimension than in the other two dimensions (very long and narrow and shallow).

o) Sliver. Sigments of plating resulting from overhang breakage.

p) Terminal areas. A terminal area is that portion of a printed circuit or wiring used for making electrical connections to the conductive pattern or component.

q) Terminal area access holes. A terminal area access hole is a hole opposite the component side of a multilayer printed cable and perforated in each layer above a terminal area, which provides access to the terminal area after laminating.

r) Visible only by refracted light. This applies to scratches that are visible only when the cable is held at a certain angle to the light and are not visible when viewed perpendicular to the surface of the cable.

s) Void. A void is localized absence of material occurring as an imperfection which penetrates entirely through any layer of a cable.

t) Whisker. A whisker is a slender needle-shaped metallic growth.

u) Inspections. When the term inspection is used herein, it is used as specified in MIL-STD-109.

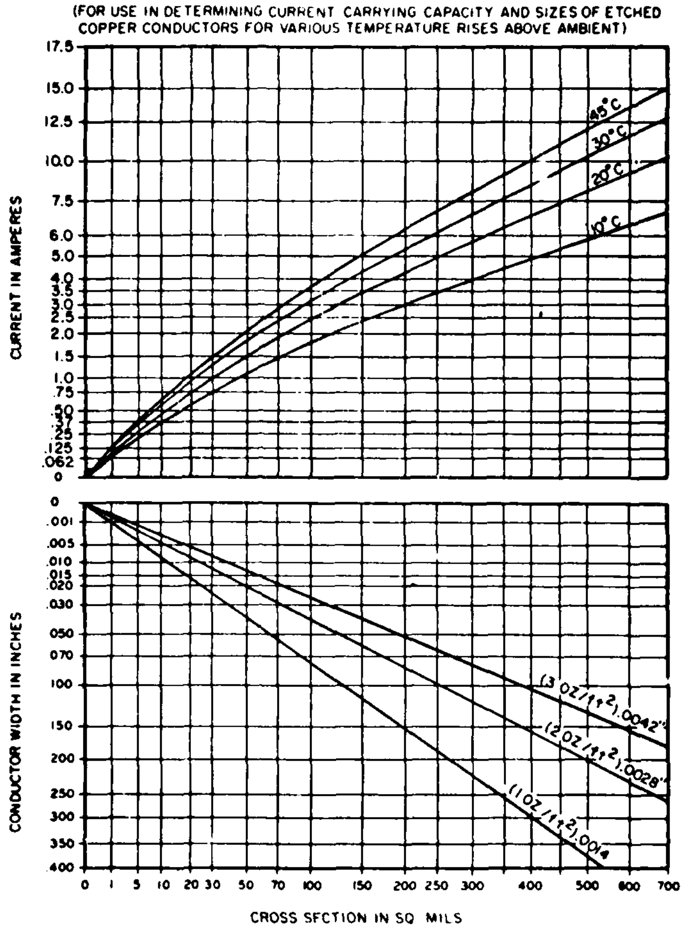
v) Classification of characteristics. Classification of characteristics shown in Tables 2, 3 and 4 are defined in terms of severity of defectives found in the test item as follows:

   1) Critical. A defect that judgment and experience indicate is likely to result in hazardous or unsafe conditions for individuals using, maintaining, or depending upon the product.

   2) Major. A defect that is likely to result in failure, or to reduce materially the usability of the unit of product for its intended purpose.

   3) Minor. A defect that is not likely to reduce materially the usability of the unit of product for its intended purpose, or is a departure from established standards having little bearing on the effective use or operation of the unit.

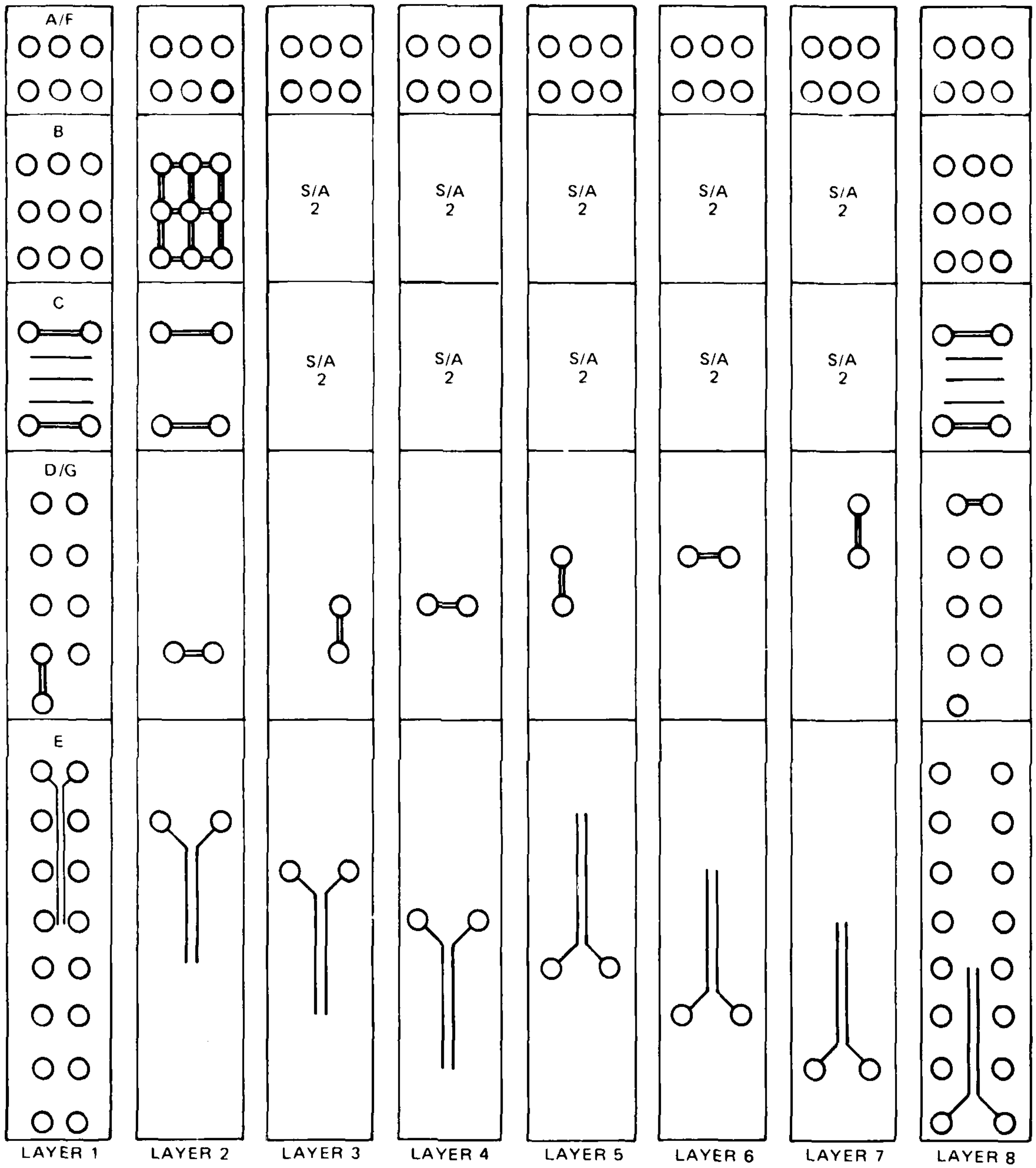
APPENDIX



NOTES:

1. The design chart has been prepared as an aid in estimating temperature rises (above ambient) vs current for various cross-sectional areas of etched copper conductors. It is assumed that normal design conditions prevail where the conductor surface area is relatively small compared to the adjacent free panel area. The curves as presented include a nominal 10 percent derating (on a current basis) to allow for normal variations in etching techniques, copper thickness, conductor width estimates, and cross-sectional area.
2. Additional derating of 15 percent (current-wise) is suggested under the following conditions:
   (a) For panel thickness of 1/32 inch or less.
   (b) For conductor thickness of 0.0042 inch(3 oz/ft^2) or thicker.
3. For general use the permissible temperature rise is defined as the difference between the maximum safe operating temperature of the laminate and the maximum ambient temperature in the location where the panel will be used.
4. For single conductor applications the chart may be used directly for determining conductor widths, conductor thickness, cross-sectional area, and current-carrying capacity for various temperature rises.
5. For groups of similar parallel conductors, if closely spaced, the temperature rise may be found by using an equivalent cross-section and an equivalent current. The equivalent cross-section is equal to the sum of the cross-sections of the parallel conductors, and the equivalent current is the sum of the currents in the conductors.
6. The effect of heating due to attachment of power dissipating parts is not included.
7. The conductor thicknesses in the design chart do not include conductor over-plating with metals other than copper.

Figure 1. Conductor Thickness and Width.



NOTES:

1. TERMINATION PADS SHALL BE 0.070 · 0.002 INCH DIA.
2. LINE WIDTHS SHALL BE 0.020 · 0.002 INCH.
3. HOLE SIZES SHALL BE THE SMALLEST SIZE SHOWN ON THE ENGRG. DWG. FOR PLATED-THROUGH-HOLES.
4. CENTER-TO-CENTER HOLE AND PAD DISTANCE HORIZONTALLY FOR CIRCUITS A/F B AND D/G IS 0.150 · 0.001 INCH. THE HORIZONTAL DISTANCE FOR CIRCUITS C AND E IS 0.300 · 0.001 INCH.
5. CENTER TO CENTER HOLE AND PAD DISTANCE VERTICALLY FOR ALL INDIVIDUAL TEST CIRCUITS IS 0.200 · 0.001 INCH.
6. TERMINAL PADS AND HOLES FOR EACH INDIVIDUAL TEST CIRCUIT HAVE COMMON CENTER LINES AND CORRESPONDING PADS IN ALL LAYERS MUST BE IN ALIGNMENT.

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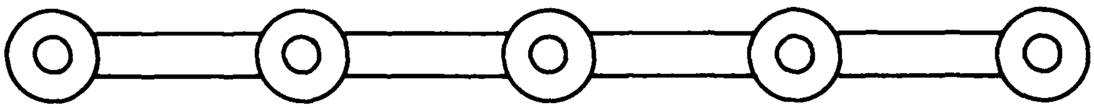
Figure 2. Quality Conformance Test Circuit in Rigid-Cable Area.



NOTES:

1. TERMINATION PADS SHALL BE 0.070 ± 0.002 INCH DIA.
2. LINE WIDTHS SHALL BE 0.020 ± 0.002 INCH.
3. HORIZONTAL PAD SPACING SHALL BE 0.100 ± 0.002 INCH CENTER-TO-CENTER.
4. ALL PADS AND HOLES SHALL HAVE A COMMON CENTER LINE.
5. ALL LAYERS SHALL HAVE THE SAME CIRCUIT CONFIGURATION.
6. HOLES SIZE SHALL BE THE SMALLEST SIZE SHOWN ON THE ENGRG DWG. FOR PLATED-THROUGH-HOLES.

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Figure 3. Quality Conformance Test Circuit in Flexible Area.

EXHIBIT 53

PROCESS SPECIFICATION FOR
RIGID-FLEX PRINTED WIRING CABLES

PROCESS SPECIFICATION

(FOR FABRICATING RIGID-FLEX PRINTED WIRING CABLES)

1. SCOPE

1.1 Scope. This specification covers the general process for fabricating rigid-flex printed wiring cables, which consist of multiple (more than one) flexible printed wiring cables stack laminated into a rigid area containing plated-through-holes as a means of inner and outer circuit connection. In conjunction with this specification are, as listed in Section 2, a series of specific process specifications which describe in detail all individual processes used to construct a rigid-flex printed wiring cable.

2. APPLICABLE DOCUMENTS

2.1 The following documents form a part of this specification to the extent specified herein.

SPECIFICATIONS

M-24-6-874	Plastic Sheet, Thin Laminate, Metal Clad, (Material Specification.
M-24-6-875	Product Specification for Fabricating Rigid-Flex Printed Wiring Cables
M-24-6-877	Copper Plating Rigid-Flex Printed Wiring Cables
M-24-6-879	Dry Gas Plasma Drill Smear Removal
M-24-6-880	Photo Engraving, Etching, and Stripping Rigid Flex Printed Wiring Cables
M-24-6-883	Laminating Rigid-Flex Printed Wiring Cables
M-24-6-885	Immersion Tin Plating Rigid-Flex Printed Wiring Cables
MIS 23659	Insulating Sheet, Polyimide, Copper Clad (Material Specification)
MIS 23661	Film, Adhesive (Material Specification)
MIS 23660	Insulating Sheet, Polyimide (Material Specification)

3. REQUIREMENTS

Parts processed according to the procedures specified in this document shall meet the requirements of Product Specification M-24-6-875.

3.1 Equipment.

3.1.1 Specific equipment requirements for individual processes will be defined in each of the appropriate process specifications referenced in Section 2.

3.1.2 All equipment shall be constructed and designed so that product tolerances can be achieved on a production basis while achieving an acceptable yield.

3.1.3 Periodic (or preventive) maintenance shall be performed on all equipment to prevent the production of sub-standard or out-of-tolerance hardware. Lubrication, replacement, and adjustment procedures shall be defined and documented.

3.1.4 All meters, gages, or other forms of equipment control shall be calibrated on a regular basis and a label indicating both the date of calibration and interval for inspection shall be attached to the device.

3.1.5 Manufacturers recommended procedures for equipment operation shall be followed. The only exceptions shall be those approved by Manufacturing Engineering, Quality Assurance, and Safety.

3.2 Materials

3.2.1 Specific material requirements for individual processes will be defined in each of the appropriate process specifications referenced in Section 2.

3.2.2 As listed in Section 2, the polyimide glass stiffener material for the subject product is controlled by material specification M-24-6-874. The copper clad polyimide flexible detail material is controlled by Material Specification MIS 23659. The adhesive film is controlled by material specification MIS 23661. The coverlayer (polyimide insulation sheet) material is controlled by material specification MIS 23660.

3.2.3 All materials used to fabricate the rigid-flex printed wiring cables shall be tested to applicable control documents prior to use, stored in clean, dry, temperature controlled, and packaged so as to preclude artificial aging or other physical or chemical damage.

3.3 Required Procedures and Operations

3.3.1 Figure A-1 in the appendix contains a process flow diagram which illustrates in detail the sequence of each individual process necessary for fabricating rigid-flex printed wiring cables. The diagram also clearly shows how the various materials are integrated.

3.3.2 The individual specifications for each process contained in the flow diagram mentioned in 3.3.1 shall be used to provide more detailed, specific information for procedures and operations.

3.3.3 The General process procedures and operations for rigid-flex fabrication are described below.

3.3.3.1 General Procedure

1. Cut the coverlayer material (polyimide insulation sheet), adhesive film, and copper clad Kapton to size using a phototrimmer, which is sharp enough to produce a clean, smooth-cut edge.

2. Cut the copper clad polyimide-glass stiffener material to size using a shear, which is sharp enough to produce a clean, smooth, nondelaminated edge.

   NOTE: The sequence of steps 3 and 4 shall be reversed for detail cables with no plated-through-holes.

3. Drill tooling, fastener, and termination holes in the above mentioned material per Table 1 in the Appendix.

4. Copper plate the copper clad Kapton to be used for detail printed wiring cables per process specification M-24-6-877.

5. Inspect the plating thickness on the surface of the panel and in the plated-through-holes. Requirements and procedures are specified in product specification M-24-6-875.

6. Photoengrave all circuit, ground plane, termination pad or other feature images on the appropriate inner layer copper clad Kapton details per process specification M-24-6-880.

7. Chemically etch the printed image on the flexible detail cables per process specification M-24-6-880.

8. Visually inspect the etched flexible detail cables using the acceptance criteria and procedures contained in product specification M-24-6-875, and the engineering drawing.

9. Laminate the coverlayer (insulation sheet) to the etched flexible detail per process specification M-24-6-883.

10. Cut the windows in the polyimide glass laminate stiffeners using a router or high-speed drill press.

11. Cut the windows in the adhesive film. The window edges shall be cut smooth and straight. The film shall not be torn, wrinkled or stretched. White cotton gloves shall be used in handling the film to prevent the transfer of dirt, oils, fingerprints etc. onto the adhesive. A clean, dry working area shall be used while cutting the film adhesive.

12. Treat the polyimide-glass laminate stiffeners and the detail cables (from step 9) with an oxygen plasma per process specification M-24-6-883.

13. Laminate the stiffeners and detail flexible cable layers together. This operation shall be accomplished using process specification M-24-6-883.

14. Drill feed through and termination holes in the rigid-flex panel using Table A-1 in the Appendix.

15. Inspect the registration of the holes to pads using Radiographic techniques (X-ray) and verify that the requirements of product specification M-24-6-875 are met.

16. Remove the drill smear from the inner circuit layers of the holes using the plasma desmearing operation in process specification M-24-6-879.

17. Copper plate the rigid-flex panel using an electroless copper plating process. This operation is performed per process specification 24-6-877.

18. Copper plate the rigid-flex panel using an electrolytic plating bath per process specification 24-6-877.

19. Inspect the plating and plated-through-hole to M-24-6-875 requirements.

20. Photoengrave images for the outer circuits and termination pads per process specification 24-6-880.

21. Etch the printed images on the outer circuit layers per process specification 24-6-880.

22. Route the rigid portion of the cable to the final design configuration using a pin router and templet. A solid carbide router bit shall be used at speeds of 15000 - 25000 RPM and feeds of 50 - 100 IPM.

23. Trim the outer perimeter of the flexible cable(s) using a metal straight edge and a sharp knife blade.

24. Ream connector fastener hole using a drill press holding fixture and pilot end reamer. The speed shall be 1500 - 2000 RPM and a gentle film pressure shall be used to feed the tool.

25. Immersion tin plate the termination pads per process specification M-24-6-885.

26. Inspect and test the rigid-flex cable per the requirements of product specification M-24-6-875.

3.4 Recommended Procedures and Operations.

3.4.1 Cutting windows in film adhesive may be accomplished using a sharp knife and a cable outer stiffener as a templet. This operation can also be performed using steel rule die cutters when it is desirable to cut sheets stacked in multiples. A platen press should be used with the steel rule die cutters.

3.4.2 Cutting windows in the polyimide glass stiffeners may be accomplished using manual or numerically controlled routing techniques. A solid carbide router bit can be used at a speed of from 15,000 to 25,000 RPM and a feed rate of 50 to 100 IPM depending on stack height. If manual routing techniques are used a routing templet shall be used to achieve repeatably accurate dimensions.

3.4.3 When reaming per operation 24, the hole should be drilled half through on each side of the cable to prevent haloing.

Operators working to this specification are not required to be certified. However, they shall be trained to perform all operations at the skill level necessary to build hardware which meets the requirements specified in M-24-6-875.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in a contract or purchase order, inspection of hardware, equipment, materials and processes shall be performed by the Quality Assurance activity of the supplier (fabricating the rigid-flex). Customer representatives may perform on-site, in-process or final inspection as directed by the procuring activity.

4.2 Monitoring Procedures for equipment. Monitoring procedures for individual processes are contained in each specific process specification listed in Section 2. In general, all equipment shall be inspected and maintained on a schedule which will assure process control.

4.3 Monitoring procedures for materials. All materials to be used directly in the rigid-flex cable product shall be initially tested per the applicable specifications listed in Section 3.

The adhesive film and polyimide insulation sheet shall be tested additionally every 6 to 12 months as directed by the applicable material specifications.

Chemical solutions, solvents, and other materials which are not part of the deliverable product shall be controlled by individual process specifications listed in Section 2. Such materials shall be stored in containers and areas which provide no danger to personnel, environment or products, and which do not promote degradation to the material itself.

4.5 Test Methods

4.5.1 Individual test and inspection methods for materials used in the process are contained in the applicable specifications shown in Section 2.

4.5.2 The rigid-flex cable shall meet the applicable product requirements contained in product specification M-24-6-875 for each level of processing shown in the process flow diagram of Figure A-1 (Appendix).

5.0 PREPARATION FOR DELIVERY - Not Applicable.

6.0 NOTES

6.1 Intended Use. The process described in this specification is the overall procedure for fabricating a rigid-flex cable. It consists of several individual processes which are integrated to produce the subject product as illustrated in process flow diagram Figure A-1 (Appendix).

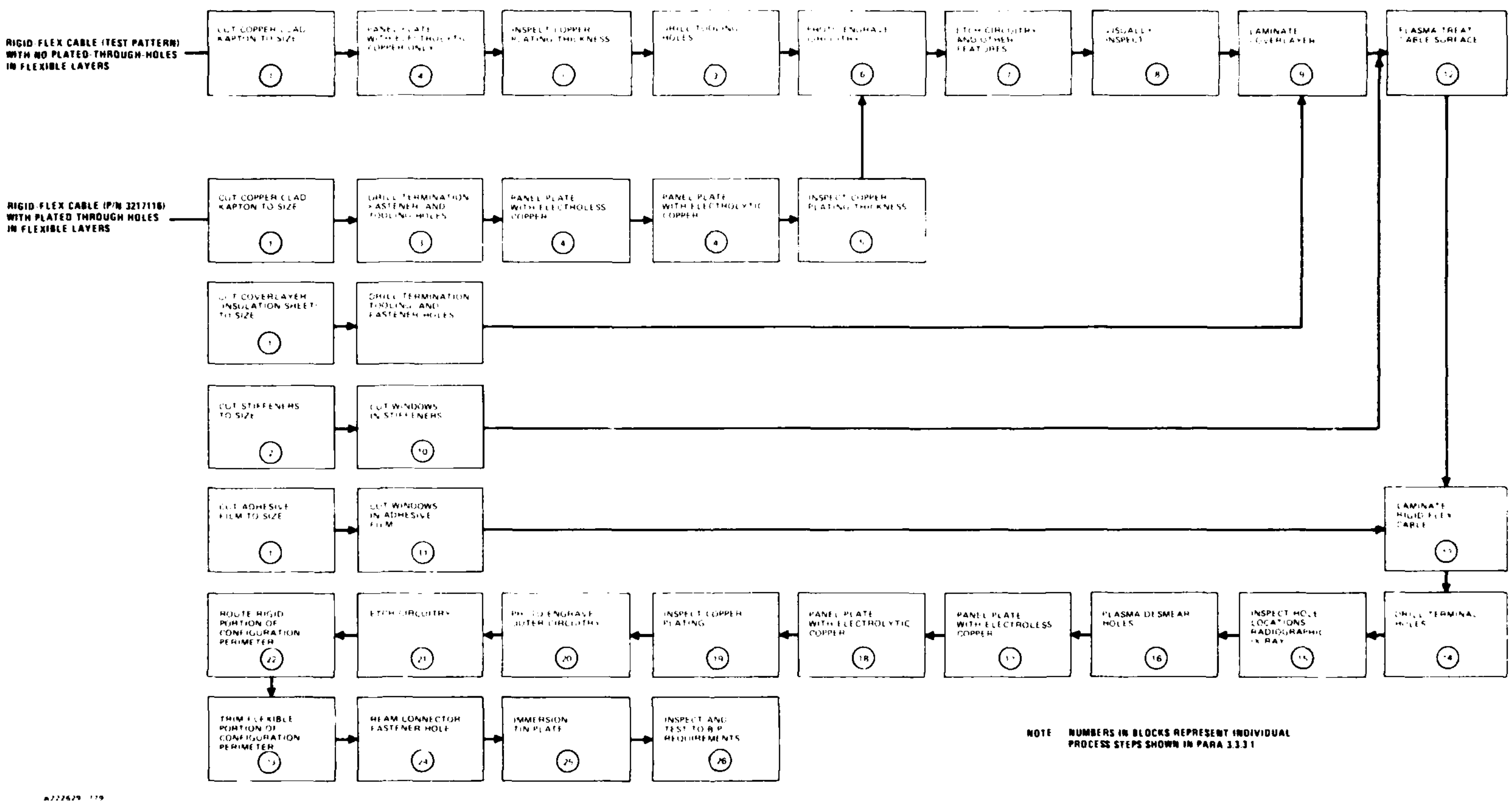

Figure A-1. Process Flow Diagram for Rigid-Flex Printed Wiring Cable Fabrication

Table A-1
DRILLING RIGID FLEX MATERIAL

Material	Drill Size	Stack Height (Units Drilled) At One Time	Speed (RPM)	Feed (IPM)	Entry Material	Exit Material
Coverlayer (insulation Sheet)	.028-.125	6 and 12	15000	30	.062 Thick Paper Phenolic	.062 Thick Paper Phenolic
	.125-.250		15000	40	.062 Thick Paper Phenolic	.062 Thick Paper Phenolic
Stiffeners	.1875-.250	6	20000	40	.005 (3003) Aluminum	.062 Thick Paper Phenolic
Film Adhesive	.1875-.250	8	15000	30	.062 Thick Paper Phenolic	.062 Thick Paper Phenolic
Copperclad Kapton	.028-.070	4	30000	40	.005 (3003) Aluminum	.062 Thick Paper Phenolic
	.073-.125		25000	40		
	.128-.250		20000	40		
Rigid-Flex Panel	.028-.125	1	15000-25000	20-30	.012 (3003) Aluminum	.080 Aluminum Foil Board

Drill Bit Configuration: Metal Removal Co., Style 265 with four facet point and 165 degree included angle.

PROCESS SPECIFICATION

FOR COPPER PLATING RIGID-FLEX PRINTED WIRING CABLES

1. SCOPE

1.1 Scope. This specification covers the copper plating process which is used to achieve plated-through-holes in rigid-flex printed wiring cables. It describes two distinct type of plating operations, first electroless copper plating, and second electrolytic copper plating.

1.2 Classification. Electrolytic copper plating specified in this specification shall be class 1 per Mil-P-14550.

2. APPLICABLE DOCUMENTS

Military

Mil-P-14550 Copper plating (electro deposited)

Mil-P-47226 Plating, copper, electroless

M-24-6-875 Product specification for rigid-flex printed wiring cables

Other

ASTM E-8 Tension testing of metallic materials

3. REQUIREMENTS

3.1 Equipment. The equipment specified herein will provide hardware which meets the requirements of M-24-6-875 and is satisfactory to the procuring activity. If equipment other than that specified below is used it must be demonstrated that the requirements in M-24-6-875 can also be met.

1) Tanks for the electroless copper plating line. All tanks for the electroless copper plating line shall be constructed of polypropylene or equivalent material and shall be of sufficient size and shape to contain the parts intended to be processed. Sufficient freeboard shall be provided at the top of each tank, and a weir and drainpipe shall be incorporated into all rinses which need circulation. The tank containing the electroless solution shall contain enough volume to prevent chemical depletion during a normal production cycle as well as through the next analysis and addition of bath constituents.

2) Heaters. Over-the-side immersion-type heaters may be used providing they can control solution temperatures to the requirement shown in Table 1 and resist chemical attack.

3) Racks. Racks shall be constructed of 416 stainless steel or equivalent and allow all areas of the panel, which are intended for plating, to be exposed. In addition the design of the rack shall provide no areas for solution entrapment and transfer.

4) Rectifiers. The rectifier shall provide sufficient ripple-free dc current to allow production capacity plating up to 30 amps per square foot (ASF).

5) Tank for electrolytic plating. The tank used to electrolytically copper plate the rigid-flex cable shall be constructed on polypropylene or equivalent material (dependent on solution used). The distance between anode and cathode (work), the anode spacing, the cathode travel (part agitation), the solution agitation (air), and other tank requirements shall conform to the plating bath suppliers' recommendations.

6) Pump and filtration system. The recommended pump type and filtration system (by the bath supplier) shall be used with the electrolytic plating tank.

7) Air blower. The air blower shall provide sufficient volume and pressure of clean (containing no oil or other contaminants) air to the spargers in the electrolytic and electroless plating tanks to produce the desired solution agitation.

8) Compressor. The compressor shall provide clean, filtered, compressed air of sufficient volume and pressure for the operation intended.

3.2 Materials. Materials which are specified herein meet the requirements contained in both M-24-6-875 and Mil-P-1455, and are satisfactory to the procuring activity. If materials other than those specified are used it must be demonstrated that the resultant plating is equal to or better than that deposited using those materials specified. Control of materials shall be achieved using individual supplier recommended test procedures.

1) Cleaner/conditioner - McDermid 9076 (concentrate)

2) Sodium persulfate

3) Sulfuric acid - ACS reagent grade

4) Hydrochloric acid - C.P. grade

5) Sodium chloride - Morton-999 Food grade

6) Catalyst (Dynachem 120)

7) Accelerometer (Shipley 19)

8) Electroless copper solution (Dynachem 240 A and B)

9) Copper sulfate solution (Sel-Rex, M&T etc)

10) Copper anodes, phosphorized (Sel-Rex)

11) Additives for copper sulfate plating bath, Sel Rex Cu bath "M" Hy

12) Mylar-film tape/silicon adhesive

13) Copper foil tape/silicone adhesive

3.3 Required procedures and operation

3.3.1 Electroless copper plating. The electroless copper plating process shall be performed sequentially as shown in Table 1, unless it can be demonstrated to the procurring authority that another procedure can perform equal to or better than that specified.

Table 1

Step #	Operation and Solution	Temperature	Time
1.	Immerse cable in cleaner conditioner (Mac Dermid 9076)	130-150°F	90-100 seconds
2.	Rinse in running tap water	Room	3-5 minutes
3.	Immerse cable in sodium-persulfate solution	80°F	90-100 seconds
4.	Rinse in running tap water	Room	60-70 seconds
5.	Immerse cable in sulfuric acid solution 10% (Vol)	Room	60-70 seconds
6.	Rinse in running tap water	Room	60-70 seconds
7.	Immerse cable in HU pre dip solution	Room	60-70 seconds
8.	Immerse cable in catalyst (Dynachem 120)	Room	5-6 minutes
9.	Rinse in running tap water	Room	60-70 seconds
10.	Immerse cable in accelerator	Room	5-6 minutes
11.	Rinse in running tap water	Room	60-70 seconds
12.	Electroless copper plate	Room	12-15 minutes
13.	Rinse in running tap water	Room	50-60 seconds
14.	Rinse in deionized water	Room	30-40 seconds
15.	Immerse cable in sulfuric acid solution 10% (Vol)	Room	60-70 seconds

3.3.2 Electrolytic copper plating. The electrolytic copper plating process shall follow the electroless plating process without allowing the cable panel to dry. The sequence of operations which follows is necessary to eliminate voids in recesses, which must be plated into.

Table 2

Step #	Operation and Solution	Temperature	Time
1.	Strike plate in a copper sulfate plating bath at 12 A.S.F. (rigid-flex only)	Room	30-40 minutes
2.	Full current plate (same bath) at 25 A.S.F. (rigid-flex only)	Room	1 hour
3.	Remove panel from bath and rinse in running tap water (rigid-flex only)	Room	60-70 seconds
4.	Immerse panel in sulfuric acid solution (rigid-flex only)	Room	60-70 seconds
5.	Full current plate - (same bath as 1 & 2) at 25 A.S.F. both rigid-flex and detail flexible cables.	Room	As required to assure 0.001 in minimum thickness in holes Recommended thickness: Detail flexible cable 0.0012 to 0.0018 inch Rigid-flex cable 0.002 to 0.0028 inch
6.	Dry panel with filtered compressed air.		As required

3.4 Recommnended procedure and operations

3.4.1 Cables processed per Table 1 should be transferred from tank to tank fast enough to prevent drying. The panel should dwell over each tank long enough to minimize solution transfer.

3.4.2 Prior to plating the rigid-flex cable all window areas (exposing Kapton) should be double masked, first with a Mylar platers tape, followed by a copper foil tape. The tape should fit the window well but should not overlap areas intended to be plated.

3.4.3 Observations of the panel to be plated should be made after steps 3 and 7 of Table 1 to determine the effect of the cleaning and pre-etch solutions. The panel should appear uniformly bright and stain free (no streaks).

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in a contract or purchase order the supplier is responsible for inspection of hardware processed to this specification as well as the process materials and equipment. If additional inspection is deemed necessary by the procuring activity it may be performed at their option.

4.2 Monitoring procedures for equipment.

4.2.1 Tanks. All chemical and rinse tanks shall be periodically checked for leaks and solution levels. The frequency shall be established according to production scheduling and work loads.

4.2.2 Gages and meters. All gages and meters shall be calibrated according to manufacturers documented procedures. The frequency of calibration shall be established and lables indicating the performance date and next due date shall be attached to each unit.

4.2.3 The electrolytic copper plating equipment and overall process shall be monitored to requirements specified on Table 2 (Appendix). Samples shall be tested for tensile strength, elongation, and thermal shock according to the sampling plan in Table 2.

4.3 Monitoring solutions. All chemical solutions shall be monitored according to Table 3 in the Appendix and periodic analysis shall be performed to meet the requirements shown. Chemical additions shall be made based on the analysis results to assure process control.

4.3.2 Anodes. The anode condition shall be inspected once each week to assure proper anode corrosion and geometry (size as it is used up).

4.3.3 Electroless copper plating. The electroless copper plating shall be sampled and tested once each production shift (8 hours) per requirements in Mil-P-47226.

4.4 Test methods.

4.4.1 Chemical solutions and materials shall be tested to procedures contained in referenced specifications in 3.2, and also to suppliers' recommendations.

4.4.2 The following physical tests shall be performed using the specifications shown.

1.	Thermal shock	M-24-6-875
2.	Tensile strength	ASTM E-8
3.	Elongation	ASTM E-8

4.4.3 Copper plating quality. Overall copper plating quality shall be tested to Mil-P-14550 requirements.

4.4.4 Each panel shall be tested to M-24-6-875 requirements either in-process or at final inspection.

6. NOTES

6.1 Intended use. The electroless copper plating process is used to deposit a conductive layer of copper on the nonconductive walls of a hole which is to be subsequently electroplated. The electrolytic (electro) plating process is used to plate over the electroless copper plating to achieve a plated-through-hole which connects inner circuit layers and outer termination pads.

APPENDIX
TABLE 3
PREPARATION AND CONTROL OF CHEMICAL SOLUTIONS

Tank For Step #	Solution	Material	Make-Up Quantity	Tank Maintenance	Minimum Analysis
1	Cleaner Conditioner MCDERMID 9076	Deionized or Distilled Water	Bal		
		MCDERMID 9076	5 (Vol)	5 ±1. (Vol)	1/week
3	Sodium Persulfate	Deionized or Distilled Water	Bal		1/day to 1/week according to work load
		Sodium Persulfate	120 g/1	100-140 g/1	
		Sulfuric Acid (Reagent)	12.32 ml/1		
5	Sulfuric Acid	Deionized or Distilled water	Bal	Surveillance Control only	
		Sulfuric Acid Reagent	98.6 ml/1		
7	Pre-Dip Solution	Deionized or Distilled Water	Bal	Surveillance Control only	Replace weekly
		Hydrochloric Acid (Reagent)	10 (Vol)		
		Sodium Chloride	180 g/1		
8	Catalyst	Deionized or Distilled Water	85 (Vol)		
		Activator (Dyna Chem)	12.5		
		Sodium Chloride	Saturated	Saturated	1/week
		Palladium		0.116-0.162 g/1	
		Stannous Chloride		13.47-18.86 g/1	1/week
10	Accelerator	Tap Water	Bal	Normality 0.180 to 0.300 N. tin	Remake bath every 3 weeks
		Accelerator 19 (Shipley)	166.66 ml/1	0.0 to 100.00 PPM Copper 0.0 to 660.00 PPM	
12	Electroless Copper	Deionized or Distilled Water			
		Dyna Chem 240 A	10 (Vol)		
		Dyna Chem 240 B	10 (Vol)		
		Copper		1.88 to 2.59 g/1	
15	Sulfuric Acid	S/A Step 5			
16	Acid Sulfate Copper Plating	Deionized or Distilled Water	Bal		
		Copper Sulfate	67.5 g/1	60 to 75 g/1	1/week
		Sulfuric Acid	172.5 g/1	150 - 225 g/1	1/week
		Iron Contamination		0.100 g/1 max	1/week
		CL		50 to 100 PPM	1/week
		SEL-REX Cubath "M" Hy	5.3 ml/1	0.5 to 1.0 ml/AMP hr	
		Copper		98.8% Min	Monthly
				Thermal Shock	2/week/No Cracks
				Tensile Strength	2/week at 300,000 PSI Min
				Elongation	2/week at 10% Min
		$CuSO_4 \cdot 5H_2O:H_2SO_4$		Ratio 1:2.55 Min	

PROCESS SPECIFICATION
FOR
DRY GAS PLASMA DRILL SMEAR REMOVAL

1. SCOPE

1.1 Scope. This specification covers the process for removing an organic coating (drill smear) from inner circuit layers within the drilled holes of multilayer rigid-flex printed wiring cables by a dry gas plasma etching system. The drill smear must be removed to prevent open circuits between the subsequent plating in the drilled hole and the inner conductive layers.

2. APPLICABLE DOCUMENTS

M-24-6-875	Product specification for rigid-flex printed wiring cables
M-24-6-876	General Process Specification for Fabricating Rigid-Flex Printed Wiring Cables.
M-24-6-877	Copper Plating Rigid-Flex Printed Wiring Cables
Part 18	Federal Communications Rules and Regulations

3. REQUIREMENTS

In order to perform the dry gas plasma smear removal process, specific equipment, materials, and procedures shall be incorporated to remove all organic material from the inner circuit layers while producing a hole wall profile which is compatible with the copper plating process used (M-24-6-877). The resultant etch-back in the hole wall shall be from 0 to 0.002 inch.

Listed below are the basic items to perform the process at a level acceptable to the procuring activity.

3.1 Equipment. Individual pieces of equipment may differ from those specified below providing it can be demonstrated that they perform equal to or better than the ones specified for the operation.

3.1.1 Plasma reactor system. The plasma reactor system consists of:

1) Reactor chamber of sufficient volume and dimension to contain the cable(s) for which it was intended to process and to produce a uniform plasma which can etch the entire cable at a uniform rate. The chamber shall be constructed of aluminum and be able to operate at pressures down to 5 torr.

2) RF power supply which has a power range compatible with the reactor chamber size and work load to be processed. Also, the power supply must operate at a frequency assigned by the FCC and contain sufficient shielding to reduce radiation emission to levels required by Part 18 of the Federal Communications Rules and Regulations.

3) Oil immersion pump capable of removing atmosphere from the chamber down to 5 torr pressure in a time which is compatible with production requirements (typically 3-7 minutes).

4) Gas cylinder(s) and regulator(s) to provide 0-20 c/c gas flow.

5) Control module shall be capable of:

(a) Initiating and terminating pump down cycle

(b) Starting, stopping, and controlling the RF Power through the entire range of operation.

(c) Initiating and terminating the introduction of gas or gases into the reactor chamber.

(d) Tuning RF circuits to achieve the minimum required reflected power loss.

A system which provides all etching characteristics necessary to conform to requirements specified in M-24-6-876 is described below. A Technics West Model 3000-1 plasma reactor meets these requirements.

1) Reactor chamber consists of a 38-inch-diameter (ID) aluminum cylinder 40 inches long. One end is closed and the other has a hinged door with a viewing window. The chamber itself acts as one electrode and an inner perforated aluminum cylindrical sleeve acts as another electrode (etch tunnel).

2) The power supply is capable of producing 2500 watts of RF power.

3) The oil immersion pump has a capacity of 100+ CFM pressure reduction.

4) Gas cylinder contains a mixture of tetrafluoromethane (CF_4) and oxygen (O_2) in the proportions of approximately 30 and 70 percent respectively.

5) The control module is a panel containing appropriate electrical toggle switches, trim-pots, and solenoid-actuated gas valves.

3.1.2 Fixtures or masks. All holding fixtures or masks shall be made of aluminum and shall be designed and constructed to perform the function required (see Appendix).

3.1.3 Vacuum oven. The vacuum oven shall be of sufficient size to contain the cable(s) intended to be processed, and provides uniform heating. In addition, a vacuum of 25-in. Hg and a temperature of 165°F must be attainable.

3.2 Materials. The only material required for the process is a mixture of compressed gases. The mixture shall consist of approximately 70 percent oxygen (O_2) and 30 percent tetrafluoromethane (CF_4). Trace amounts of nitrogen are acceptable in the mixture. The usual bottle pressure, which as initially received, is 500 psig.

3.3 Required Procedures and Operations. The following step by step procedure is provided as a description of all operations in the Plasma Smear Removal Process.

> NOTE: It should be noted that exact power, gas flow and time cycle parameters shall be established for each individual plasma reactor and for each individual part configuration. The specific process cycle parameters shown in Table 1 of the Appendix are those compatible with the reactor described in 3.1.1 for two different eight-layer, 0.062-in.-thick, two-ounce copper, rigid-flex printed wiring cables.

1) Prebake. The cable shall be baked in a vacuum oven at a temperature of 165 ± 5°F and a pressure of -25 ± 1 in. of Hg for 1-2 hours prior to processing.

2) Warmup. The plasma reactor shall be operated at normal operating parameters for 15-25 minutes prior to processing any cables. This shall be accomplished using the same gas mixture, pressure, gas flow and power settings as are used during actual process cycling (see Table 1).

3) Fixturing. The cable shall be restrained in a suitable holding fixture or mask prior to and during the process cycle. An illustration of a typical holding fixture or mask is shown in Figure 1 (Appendix).

4) Plama Process Cycle. The process shall be performed as follows:

   a) Place the fixtured cable(s) into the plasma reactor chamber such that it is suspended and is as symetrically located and centered as possible. If more than one cable is processed, assure that adjacent cables will not be so close to each other that they will cause nonuniform etching.

b) Close the reactor door and pump the chamber pressure down to 5-30 torr allowing the pump to continue to reduce pressure.

c) Introduce the mixed gas until a stable 200 torr pressure is attained (the pump is still pumping down).

(d) Turn on the RF power and adjust the setting to the required value (see Table 1, appendix). A bluish white glow is an indication of the proper plasma generated, as observed through the viewing window in the door. Tune the reflected power to zero.

e) Allow the process to proceed for the full cycle time period (see Table 1, Appendix).

f) Turn off RF power and mixed gas flow and vent out the spent gases while continuing to pump down for 1-2 minutes.

g) Discontinue pump-down and allow the chamber to reach atmospheric pressure.

h) Remove cable from chamber and recycle as needed.

If the plasma reactor is equipped with an automatic cycle control, the specific process parameters shall be programed into the machine manually during the warmup cycle.

3.4 Recommended procedures and operations.

3.4.1 Resurfacing of cable. Prior to performing the plasma desmearing operation, the cable should be resurfaced in order to remove surface contamination and burrs at the edges of drilled holes. A rotary bristle brush, pumice and water, or a Scotchbrite pad and water may be used to perform this operation.

3.4.2 Cleaning the chamber and seal. The chamber door sealing surface and seal should be wiped with Isopropyl alcohol and lint free cloth periodically (once each 4 or 5 cycles-typical) in order to achieve a tight vacuum seal. The inside of the chamber and door should be wiped with Isopropyl and a lint free cloth weekly, or more often, to remove residue materials which accumulate.

3.4.3 Window areas. Window areas which contain Kapton flexible cable material should be masked with tape which is compatible with the plating process (see M-24-6-877) and which can withstand the effects of the plasma. Typically a mylar film, coated with silicone adhesive, is used for this purpose.

It may be necessary to pierce the window in an area outside of the cable configuration in order to prevent a ballon effect at the low pressures used in both vacuum baking and plasma desmearing. This can be done with a sharp knife blade. The pierced area should be remasked with tape prior to plating.

3.4.4 Measuring plasma etch-back effect. The effect of this process can only be determined by plating the cable (see M-24-6-877) and cross sectioning the test circuits provided on the panel containing the rigid-flex cable. The cross section shall indicate results conforming to the requirements specified in product specification M-24-6-875.

3.4.5 Controlling amount of etch-back. Since the rate of etching is dependent on part and chamber temperature it is necessary to maintain temperatures within a range. The range must be established for individual units of equipment and process parameters. The typical range for the equipment illustrated in this specification is 100°F to 160°F. It should be noted that as the equipment is continually used, the temperature increases and it is necessary to allow for cooling between cycles.

4. Quality assurance provisions.

4.1 Responsible for inspection. The supplier (fabricating the cable) is responsible for all inspection operations. At the option of the procuring activity, additional in process or final inspection may be performed by their personnel when deemed necessary.

4.2 Monitoring procedures for equipment. The supplier shall perform periodic surveillance of equipment to assure that degradation of the equipment is not causing discrepant hardware to be produced. Items which shall be monitored include:

1) All gages and meters shall be calibrated on a regular basis as indicated by a calibration label displaying the date of calibration and next due date. Calibration shall be performed according to established documented procedures specified by the equipment manufacturer. The frequency of calibration shall be established according to functional need.

2) Vacuum pump oil is changed as prescribed by the pump manufacturer within a period which is based on production loading and oil life characteristics.

4.3 Monitoring procedure for materials. Items which shall be monitored are listed below.

1) Compressed gas shall be stored in cylinders which are safe to operation areas and personnel.

2) Gas storage cylinders shall be inspected for correct gas composition, safe mounting and adequate capping (while being stored).

3) Pressures contained in the cylinders shall not only be within safe operating limits of that specific cylinder type but also sufficient to provide the pressure and volume requirements of the plasma reactor.

4.4 Test Methods

4.4.1 Plated-through-hole cross section. Cross sectioning techniques and requirements are contained in product specification M-24-6-875.

5. PREPARATION FOR DELIVERY - N/A

6. NOTES

6.1 Intended use. The process described in this specification is used to remove an organic coating left on inner conductive layers in drilled holes of multi-layer rigid-flex printed wiring cables. The coating (drill smear) is not always present, but it is necessary to perform this process in order to be assured that no open circuits exist between plated holes and inner circuit layers.

APPENDIX

Table 1
PROCESS PARAMETERS FOR TWO EIGHT LAYER RIGID FLEX CABLES

Part/ Configuration	Gas	Total Operating Pressure	Initial Pump Down Pressure	Power	Plasma On-Time
P/N 3217116	Mixture of 30% cF_4 70% O_2	200 Torr	5 Torr	2000 Watts	20 Min
Test Pattern/ NOSC contract N00123-77-C-1192	Mixture of 30% cF_4 70% O_2	200 Torr	5 Torr	2000 Watts	14 Min

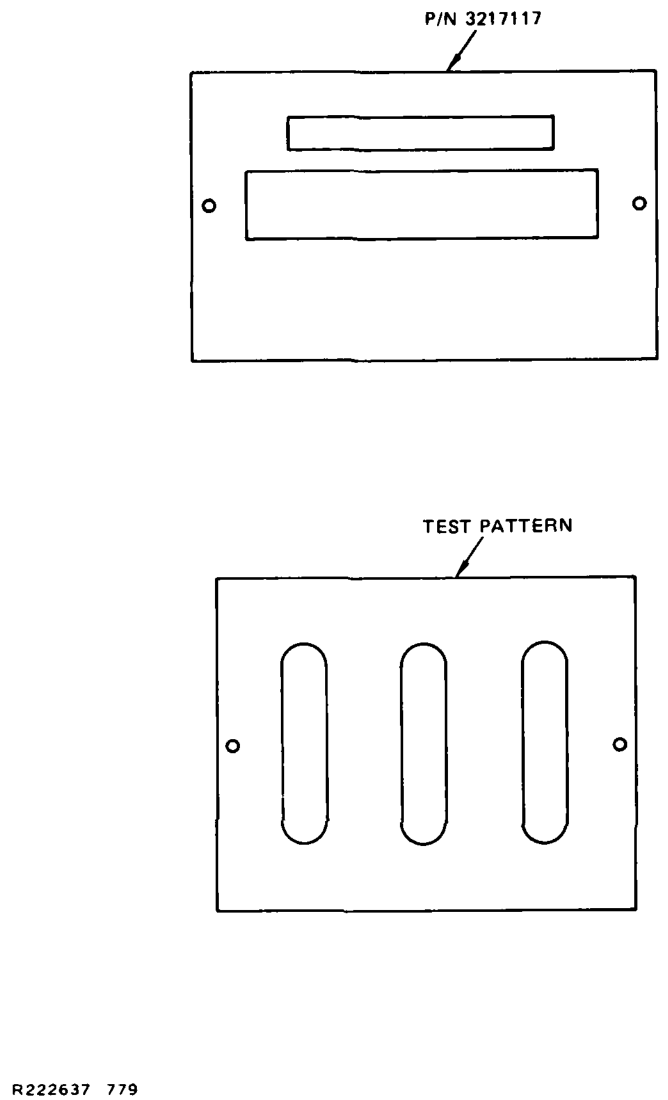

Figure 1. Fixtures (Masks) Used for Holding Rigid-Flex Cables are Constructed of 1/8-Inch Thick Aluminum Plates With Cut-Outs Located to Expose Holes

PROCESS SPECIFICATION
FOR
PHOTOENGRAVING AND ETCHING RIGID-FLEX PRINTED WIRING CABLES

1. SCOPE

1.1 Scope. This specification covers the process of photoengraving, etching and stripping rigid-flex printed wiring cables. The process uses a dry film photo-resist image to mask the circuit pattern while the exposed copper is removed with a chemical etchant. The photo-resist is then stripped from the etched circuitry.

2. APPLICABLE DOCUMENTS

M 24-6-875

3. REQUIREMENTS

3.1 Equipment. Equipment described below will produce hardware which meets the requirements specified in M-24-6-875 and it is approved by the procuring activity. If equipment other than that described is used, it must be demonstrated that the hardware produced will also meet the requirements specified in M-24-6-875.

3.1.1 Chemical etcher. The chemical etcher shall be capable of etching copper at a uniform rate by providing an even spray and movement of chemical solutions across the copper clad panel. The etcher shall be able to control conveyor speed and temperatures within the limits required.
The etcher shall be constructed of materials which are compatible with the chemical solutions contained. A chem-cut 547 conveyorized etching system is acceptable for this application.

3.1.2 Dry film laminator. A hot roll or hot shoe laminator which will apply dry film resist with sufficiently uniform adhesion to withstand the subsequent chemical attacks shall be used. The laminator shall not cause excessive tension in the resist being applied to the panel. A Du Pont MNo. #HRL-24 hot roll laminator is acceptable for this application.

3.1.3 Developer system. A developer system which will uniformly spray the entire exposed panel shall be used. A means of rinsing the developer residue shall be incorporated into the machine or system. It must be capable of developing clean, sharp circuit images across the entire panel which is being processed. A Du Pont A-24 or ADS-24 developer system is acceptable for this application.

3.1.4 Dryer. A dryer which incorporates a clean, dry, air supply shall be used to remove water and moisture from the panel. It shall dry the panel without leaving excessive streaking or residue. A chem-cut Mo #547 is acceptable for this application.

3.1.5 Exposure system. A light exposure system shall be used that can produce circuit line widths to tolerance specified on the engineering drawings. A gyrex number 905 light exposure system is acceptable for this application.

3.1.6 Tanks. Tanks used to contain processing solutions and water rinses shall be of sufficient size and volume to contain the parts intended to be processed. Adequate freeboard, drainage provisions, and weirs (rinse tanks only) shall be provided. The materials of construction shall be such that the tank can withstand chemical attack and temperatures of solutions contained.

3.1.7 Heaters. Heaters shall have sufficient capacity to maintain the temperatures of solutions specified in 3.3.

Over-the-side immersion type heaters may be used providing they can withstand chemical attack of the solutions to be heated. Temperature controllers shall be provided which will operate heaters within limits specified in 3.3.

3.1.8 Touch-up and examination station. A clean dry area which contains a lighting fixture, table, chair, magnifying glass, brushes, knives, etc., specifically designed for touch-up of photo resist shall be used for rework of resist images.

3.1.9 Photo tools. Photo tools can be made from either glass or polyester film which has been coated with a silver halide emulsion (photo sensitive). Recommended glass thickness is 0.190 inch and film thickness is 0.007 inch.

3.1.10 Pumice scrubber. A hand or air-motor-driven bristle brush can be used to wet scrub the panels prior to the dry film application.

3.2 Materials. Materials described below will produce hardware which meet the requirements specified in M-24-6-875 and are approved by the procuring activity. If materials other than those described are used, it must be demonstrated that the hardware produced will also meet the requirements specified in M-24-6-8254.

3.2.1 Pumice. Commercial Grade FFFF.

3.2.2 Cleaner. Lonco-Terge CU3

3.2.3 Dry film photo resist. A photo resist system which is compatible with the Kapton-Acrylic laminate used for rigid-flex cable manufacture shall be used. Riston 218R is acceptable for this application.

3.2.4 Developer-Solution. A developer recommended by the dry film resist manufacturer shall be used. Du Pont, Riston developer 2000 is acceptable for Riston 218R resist.

3.2.5 Dry film resist stripper. The stripper shall remove the photo resist without leaving a residue on the surface and without damaging the cable. Riston 1100X is acceptable for removing Riston 218R resist.

3.2.6 Hydrochloric acid. APC grade.

3.2.7 Etchant. An etchant capable of removing the clad copper without damaging the resist or cable shall be used. Ferric chloride, chromic sulfuric, and cupric chloride systems are acceptable in this application.

3.2.8 Scotch-brite abrasive pad.

3.2.9 Touch-up ink - Warnow plating resist PR 4001.

3.2.10 Methyl Ethyl Ketone (MEK

3.3 Required Procedures and Operations. The following operations shall be performed in sequence to meet the requirements specified in M-24-6-875. If other procedures and operations are used it must be demonstrated that the same requirements in M-24-6-875 are also met.

3.3.1 Cleaning the panel. The surface of the panel to be coated with dry film resist shall be scrubbed using either an air-motor-driven rotary bristle brush, pumice, and water, or using a Scotchbrite pad and water. The scrubbing operation shall be followed by a 15 to 20-second dip in the cleaner Lonco Cu 3) solution followed by a 40 to 50-second rinse in running tap water.

3.3.2 Drying and baking. The panel shall be dried with clean dry air (filtered compressed, or blown) immediately following the cleaning operation (3.3.1) to prevent streaking and oxidation. The panel shall then be baked in a convection oven for 15 ± 5 minutes at 150-165°F.

3.3.3 Dry film resist coating. The dry film resist shall be laminated to the panel using a Riston dry film roller coater according to the manufacturers instructions (temperature, roller speed etc.). A Mo #HRL-24 Riston hot roll laminator is acceptable.

3.3.4 Trimming excess resist. Excess resist shall be removed from the panel edges with a sharp knife blade (razor blades are acceptable).

3.3.5 Piercing photo tool alignment holes. The resist covering the photo tool alignment holes shall be pierced with a hot (400-500°F) conical soldering iron tip. Care shall be exercised in this operation to prevent hole enlargement or distortion.

3.3.6 Exposure of photo image. The photo tool (film or glass light mask) shall be aligned on the panel using the appropriate tooling pins and

holes prior to exposure. The panel shall be exposed to UV light in a Gyrex 905 exposure system for the time (dependent on light source traverse speed) necessary to produce a clean, sharp, circuit image.

> NOTE: The exposure time shall be established using a light density step wedge according to the resist manufacturer's recommendations.

3.3.7 Development of resist image. The resist image shall be developed using a Riston A-24 or ADS-24 development system and Riston 2000 developer (mixed to manufacturers recommended concentrations). Development time shall be established empirically to produce a clean, sharp visual image with no resist residue (scumming) left on areas to be etched. After exposure of the panel, and prior to development there shall be a 1-hour delay period.

3.3.8 Drying the panel. After developing the resist image, the panel shall be dried in still air for 30 minutes minimum.

3.3.9 Examination and Touch-Up. The panel shall be examined for resist images which are incomplete, poorly bonded, or are in addition to that needed. A liquid resist (ink) shall be coated on areas which are not complete. The poorly bonded resist shall be removed with a sharp blade and reapplied with a brush as a liquid (ink). The resist which is in addition to that needed shall be removed with a sharp knife blade. Liquid resist shall be dried sufficiently to withstand chemical erosion action during etching.

3.3.10 Etching the copper circuit pattern. The copper circuit pattern shall be produced in an etching machine which provides uniform solution impingment (spray) and circulation across the panel being processed. The etching solution may be ferric chloride, cupric chloride, chromic sulfuric or another, providing it can etch the circuit dimensions specified in M-24-6-875 and on the engineering drawing. In addition the solution shall not damage the cable being processed.

A chem-cut 547 etcher and dryer are acceptable for producing cables to this specification.

> Note: The supplier's recommendations shall be followed when using a given etch time. The conveyor speed or etch time shall be established empirically in order to control etched dimensions.

3.3.11 Stripping the photo resist. The photo resist shall be removed by either method 1 or 2 described below.

Method 1

1. Immerse in Riston 1100X stripper at 150 $\pm$ 5°F for 3-5 minutes. Use the minimum time for resist removal.
2. Rinse in running tap water for 50-60 seconds.
3. Air dry using clean, dry, forced air (filtered, compressed or blown).

Method 2

1. Immerse in methyl ethyl ketone (bath #1) 50-79 seconds. Use the minimum time for resist removal. Bath #1 is used to remove resist.
2. Immerse in methyl ethyl ketone (bath #2) 5-10 seconds. Bath #2 is a rinse only and should follow bath #1 immediately.
3. Rinse in running tap water for 50-60 seconds.
4. Air dry using clean, dry, forced air (filtered, compressed or blown).

3.4 Recommended procedures.

3.4.1 Scrubbing the flexible copper clad Kapton laminate. The flexible cable material should be placed on a firm rubber backing while being scrubbed to prevent damage. Also, the panel should be kept wet during this operation.

3.4.2 Handling flexible copper clad material. The flexible cable material should be interleafed between sheets of paper, cardboard, or foamed polyethylene to prevent bending, folding or other damage while it is not being processed.

3.4.3 Etching. When using conveyorized etching equipment, a rigid leader board (0.062 epoxy glass laminate, typical) should be taped ahead of the flexible panels to be processed. This prevents the cable from being caught and damaged in the etching machine.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for inspection of fabricated hardware, processing equipment, and materials used in this process.

4.2 Monitoring procedure for equipment

4.2.1 Meters and gages. All meters and gages on equipment shall be calibrated according to manufacturer's documented procedures. The frequency shall be established to assure process control during the period between successive calibrations. A label shall be attached to each calibrated unit indicating the day of calibration and the next due date.

4.2.2 Heaters controls. The heater controls shall be calibrated per manufacturer's documented procedures. The frequency of calibration shall be established so that temperatures required in (3.3) can be maintained between successive calibrations. A label shall be attached as described in 4.2.1.

4.2.3 Light exposure systems. The Gyrex 905 exposure system shall be checked weekly with a light density step wedge to assure that UV lamp output is compatible with process exposure times or speeds. The dry film photo resist manufacturer's recommended step number shall be used to maintain process control.

4.3 Monitoring procedures for material.

4.3.1 Tests for materials described on supplier's specification sheets shall be performed for individual materials contained in 3.2. The frequency of such tests shall be established to control incoming material quality within useful limits.

4.4 Test methods. Test methods for materials listed in 3.2 shall be provided by individual material suppliers.

5. PREPARATION FOR DELIVERY. N/A

6. NOTES

6.1 Intended use. The photo engraving, etching, and stripping process described in this specification is used to obtain the circuit pattern on both the individual flexible cables which go into a rigid-flex cable and the outside stiffeners of the rigid-flex printed wiring cable.

PROCESS SPECIFICATION
FOR
LAMINATING RIGID-FLEX PRINTED WIRING CABLES

1. SCOPE

1.1 Scope. This specification covers the laminating process used to apply the Kapton insulation sheet (coverlayer) to individual flexible printed wiring cables and also the process used to bond all individual flexible cables to the outside stiffeners forming a rigid-flex printed wiring cable.

2. APPLICABLE DOCUMENTS

M-24-6-875 Product specification for rigid-flex printing wiring cables.

3. REQUIREMENTS

The equipment, material, and procedures specified below will perform this process at a level which produces hardware conforming to product specification M-24-6-875.

3.1 Equipment. The equipment described below is necessary to perform the process shown in 3.3 and is acceptable to the procuring activity. Equipment other than that specified shall only be used when it can be demonstrated that it performs equal to or better than the accepted units described.

3.1.1 Laminating press. The laminating press shall have the following capacity and characteristics:

1) Platens of sufficient size to contain the bonding fixture and provide a 1-inch-wide margin on the perimeter.

2) Ram force sufficient to provide a pressure of 100 to 500 psi.

3) Electrical platen heaters which will bring the bonding fixture and part up to temperature in 10-15 minutes and control platens to ± 25°F uniformity.

4) Water cooling system which will reduce platen temperature to less than 100°F from laminating temperature in approximately 30 minutes.

5) Timer should be provided which can control cycle duration per requirements specified in 3.3.2 step 6.

3.1.2 Bonding Fixtures. The bonding fixture (shown loaded in Figures 1 and 2) shall consist of the following:

1) Top and bottom caul plates shall be constructed of either aluminum or carbon steel and must be large enough to provide a 1/2-inch-wide perimeter surrounding the panel being laminted. The thickness of the plates is typically 1/2 inch. The plates shall contain tooling pin holes that match the tooling holes drilled in the cable detail materials.

2) Top and bottom liners shall be constructed of 0.030-inch-thick stainless steel and must contain tooling holes matching those in the caul plates described above. The size of the liners should also match the caul plates, and the surface finish shall be a maximum of 30 microinches (RMS).

3) Top and bottom rubber pads shall be 0.062-inch thick and contain the same tooling hole size and location as the caul plates and liners. The rubber shall be a high-temperature resistant silicone type which is reinforced with one ply of glass cloth.

4) Steel tooling pins shall provide a snug slip fit in the cable detail layers and in the silicone rubber pads.

3.1.3 Vacuum oven. The vacuum oven used to remove moisture from detail material shall be large enough to contain the quantity and volume of work to be processed. It must be capable of heating the work uniformly to 165 $\pm$ 10°F while providing a -25 in. Hg reduced pressure (max.).

3.1.4 Tanks. Tanks used to hold the cleaner, water rinses, sodium persulfate and phosphoric acid, shall conform to the following and shall provide sufficient volume, dimension, and freeboard to contain parts for which the process is intended.

- Tank for cleaner - The tank which holds the cleaning solution shall be constructed of a material which resists attack from acid cleaners, and which can withstand the temperature specified for use (see Table 1). Polypropylene, or coated (polyvinyl chloride-acceptable) steel tanks are adequate, providing the wall thickness will support the volume of solution contained.

- Tanks for water rinse (Room Temperature) - The tanks shall be constructed of a material which does not rust, corrode, degrade, or produce a product which is detrimental to the hardware being processed. Stainless steel, epoxy glass, coated steel, polypropylene, or polyvinyl chloride are adequate providing the wall thickness will support the volume contained. The rinse tank should contain a weir and drainpipe to allow skimming of surface contaminations and circulation.

- Tanks for sodium persulfate and phosphoric acid solutions. These tanks shall be constructed of a material that will not degrade or produce a product which is detrimental to the hardware being produced when exposed to the solution contained. Polypropylene or polyvinyl chloride are acceptable materials for this application.

3.1.5 Heaters. Heaters for both the cleaner and hot water rinses may be of the over-the-side immersion type. The heaters shall be constructed to provide sufficient heating capacity and also adequate resistance to chemical attack. A temperature control device shall be provided to maintain temperature specified in Table 1.

3.1.6 Air compressor or dryer. The source of compressed air must be such that the subject hardware can be dried without leaving any oil or other residue on the surface. If an air compressor is used it must contain a filter to assure oil removal.

3.1.7 Work areas. Areas in which this process is performed should be environmentally controlled for the following:

1. Temperature. The area temperature should be controlled from 65°F to 95°F.
2. Humidity. The area humidity should not exceed 50% nor fall below 10%.
3. Dust level. The area should provide a means of controlling dust or other contamination. No specific clean room requirements are imposed but it is recommended that air flow benches be incorporated into lay-up facilities.

3.2 Materials. The materials described below are necessary to perform the process shown in 3.3 and are acceptable to the procuring activity. Materials other than those specified shall only be used when it can be demonstrated that they perform equal to or better than the accepted materials.

3.2.1 Release sheet. A 0.001-inch-thick teflon film shall be used as a parting material between the laminated panel and the silicone rubber pads (see Figures 1 and 2).

Prepunched holes to accommodate tooling pins may be provided.

3.2.2 Window plug. Polyimide glass laminate which is 0.010-inch thick copper clad one side only, and cut to fit window areas in the cable stiffeners shall be used as plugs to more equally distribute pressure. The plug shall be from 0.020 to 0.040 inch smaller in both length and width dimensions than the stiffener window (see Figure 2).

3.2.3 Pressure equalization pad. Teflon film which is 0.005-inch thick shall be used as a pressure equalization pad material. (See Figure 2.)

3.2.4 Separation insert. Teflon film which is 0.005-inch thick shall be used as a separation insert (see Figure 2).

3.2.5 Insulation sheet (Coverlayer). Conforming to engineering drawing requirements (containing all required holes and cutouts).

3.2.6 Adhesive film conforming to engineering drawing requirements (containing all required holes and cutouts).

3.2.7 Etched circuit detail cables conforming to engineering drawing requirements (containing all required holes, cutouts and plating).

3.2.8 Polyimide glass laminate stiffeners conforming to engineering drawing requirements (containing all required holes and cutouts).

3.3 Required Procedures and Operations. Two distinct lamination procedures are described below. The first covers the application of insulation sheet (coverlayer) to detail flexible printed wiring cables. The second covers the lamination of all individual flexible cables to polyimide glass stiffeners forming the rigid-flex printed wiring cable. Any deviation from prescribed procedures requires a demonstration that the deviation produces hardware equal to or better than that produced as described below.

3.3.1 Insulation sheet (cover layer) Lamination Operation. The following step by step procedure describes this lamination operation.

1) Cleaning the printed wiring flexible detail cables. Perform all operations shown in Table 1 on individual detail cables prior to lamination.

Table 1

#	Operation and Solution	Temperature	Time
1.	Immerse cable in hot acid cleaner	140-160°F	30-40 seconds
2.	Rinse in running tap water	Room	50-60 seconds
3.	Immerse cable in sodium persulfate solution	Room	15-25 seconds
4.	Rinse in running tap water	Room	50-60 seconds
5.	Immerse cable in phosphoric acid solution		20-30 seconds
6.	Rinse in running tap water	Room	50-60 seconds
7.	Force dry with filtered compressed, or blown air		As required

2) Baking the detail cable. The cable shall be baked at 165° $\pm$ 10°F for 1 to 2 hours in a reduced pressure of -25 in. of mercury (max.) This operation must precede the lay-up of all details by no more than 30 minutes.

3) Baking the insulation sheet. Individual sheets of insulation (coverlayer) shall be baked for 20 minutes according to 2) above. A 30 minute maximum delay is allowed prior to lay-up.

4) Laying-up detail layers. All detail layers shall be layed-up as shown in Figure 1 starting with the bottom caul plate and proceeding to the top. It is necessary to remove all carrier backings from the insulation sheet prior to lay-up and to position the adhesive side next to the printed detail cable. In addition, use care in sliding the cable on tooling pins to prevent hole tearing or distortion.

5) Laminating. The bonding tool which contains the details to be laminated shall be centered between press platens and be laminated using the following cycle parameters:

   a) Start temperature - less than 100°F

   b) Platen pressure 350-450 psi

   c) Cure temperature 370°F (controller setting)

   d) Cure time 1 hour $\pm$ 10 min.

   e) Cycle stop temperature less than 100°F.

6) Disassembly. The laminated cable shall be removed from the bonding tool carefully by pressing the tooling pins out of the cable (opposed to pulling the cable off the pins). This minimizes tooling hole distortion and promotes more accurate registration at the next lamination operation.

3.3.2 Rigid-flex cable lamination. The following step by step procedure describes this lamination operation.

1) Cleaning the flexible cables and stiffeners. The flexible cables to be laminated shall be wiped thoroughly with methol ethyl-ketone (MEK) and a lint free cloth.

2) Baking flexible cables and stiffeners. The cables and stiffeners shall be baked at 165° $\pm$ 10°F for 60-90 minutes. At a reduced pressure of -25 in. of mercury (max.)

3) Surface treating of flexible cables and stiffeners. The flexible cables and stiffeners shall be treated with a dry gas plasma process. The equipment and procedures shall meet the requirements specified in M-24-6-879. The operating cycle parameters are described below.

a) Gas - oxygen (O_2)

b) Pump-down pressure - 10 to 50 torr

c) Total pressure (with oxygen introduced) 200 torr

d) Power must be compatible with equipment and load (2000 watts can be used for equipment described in M-24-6-879).

e) Time for plasma exposure - 3 to 5 minutes

4) Baking flexible cables and stiffeners (optional). The flexible cables and stiffeners shall be baked for 60-90 minutes as described in 2) above if more than 30 minutes elapse from the plasma treatment 3) until the lay-up operation.

5) Laying-up detail layers. A detail layers shall be layed-up as shown in Figure 2, starting with the bottom caul plate and proceeding to the top. It is necessary to remove all carrier baking from the adhesive film prior to lay-up. The pressure equalization pads shall be placed entirely within the copper borders of all flexible cables and must overlap the part configuration sufficiently to transfer any air entrapment to an area outside the part envelope.

6) Laminating. The bonding tool which contains the detail layers to be laminated shall be centered between press platens and laminated using the following cycle parameters:

a) Start temperature - less than 100°F

b) Platen pressure - 350 - 400 psi

c) Cure temperature 370°F (controller setting)

d) Cure time 2 hours + 10 minutes

e) Pressure release temperature - less than 100°F

7) Disassembly. The laminated cable shall be removed from the bonding tool carefully by pressing the tooling pins out of the cable (opposed to pulling the cable off the pins). This minimizes tooling hole distortion and promotes more accurate location at next driling operation.

3.4 Recommended Procedures and Operations

3.4.1 Contamination control. All work should be performed in areas which provide adequate control of contaminating materials (dust, moisture, solvents, gases, etc.) to reduce entrapment of foreign substances in the laminate and to promote bond strengths to levels specified in M-24-6-875.

3.4.2 Material handling. Operators should use lint free cotton gloves to handle all detail part layers to be laminated. The individual layers should only be touched on the edges to prevent surface contamination. The detail layers should be handled with care, to prevent damage, and stored between separators which prevent both contamination and physical damage.

4. Quality assurance provisions

4.1 Responsibility for inspection. The supplier is responsible for the inspection of all equipment, materials, and hardware covered in this specification. Inspection other than that required of the supplier may be performed at the option of the procuring activity either in process or final.

4.2 Monitoring procedures for equipment

4.2.1 Surveillance of work areas shall be provided to assure that work area environmental conditions conform to those required in 3.1.7.

4.2.2 All gages and meters shall be calibrated according to manufacturer's documented procedures. Frequency of inspection shall be established according to individual needs. Labels shall be applied to such gages or meters indicating the date performed and next due date.

4.2.3 Press temperature uniformity shall be determined on a regular basis by a means which provides adequate detection of faulty platen heaters or inefficient platen cooling mechanisms.

4.2.4 Lamination press platen parallelism shall be measured periodically (based upon individual lamination press needs) and adjusted to manufactuer's requirements.

4.3 Monitoring procedures for materials.

4.3.1 Chemical solutions used for cleaning parts in this specification shall be inspected, controlled and analyzed per Table 1 in the Appendix.

4.3.2 Periodic inspection of the adhesive film and the insulation sheet shall be performed according to MIS 23661 and MIS 23660 respectively. Surveillance of the roll material (before cutting into detail units) shall be performed to assure compliance with the referenced specifications.

5. NOTES

5.1 Intended use. This specification shall be used when laminating insulation sheet (coverlayer) to detail flexible printed wiring cables which will be subsequently laminated into a rigid-flex printed wiring cable. The specification is also used to laminate all detail layers of a rigid-flex cable together.

5.2 Definitions

5.2.1 Detail. When used in this specification detail indicates that a part, cable, harness, or other piece of hardware which is at a lower indenture level (at a level which goes into another level of assembly).

5.2.1 Lay-up. Lay-up is a term used to show that a series of cable layers are being assembled in a predetermined sequence.

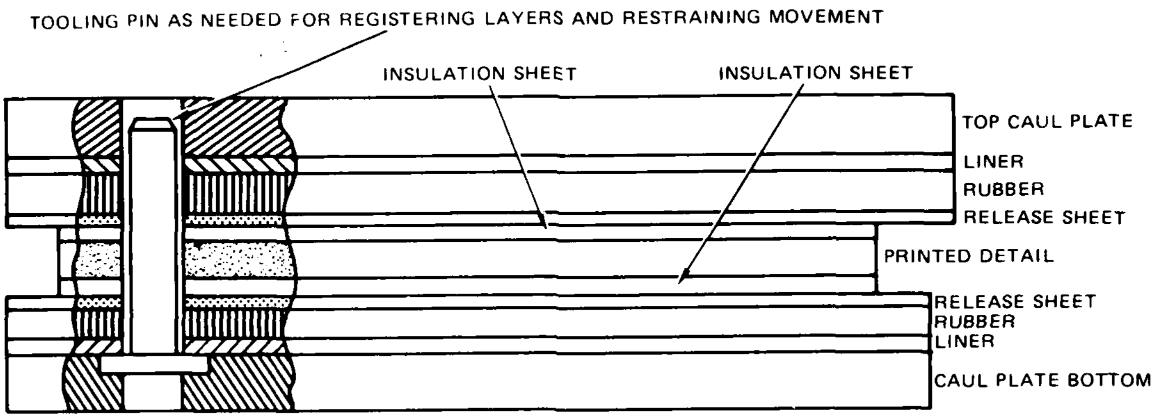

Figure 1. Showing Lamination Tooling and Detail Layers for Bonding Insulation Sheet (Coverlayer) to Etched Printed Wiring Cable

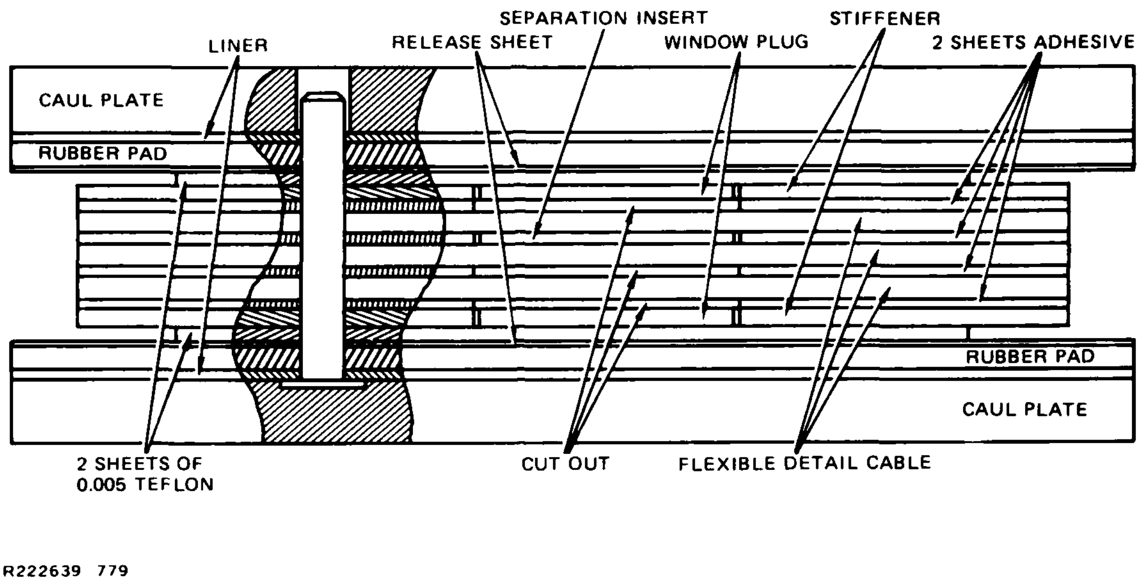

Figure 2. Computer Lay-Up of All Detail Cable Layers in Laminating Tool (Not to Scale)

APPENDIX

TABLE 1. SOLUTION MAKE-UP AND MAINTENANCE

Operation	Solution	Material	Make-up Quantity	Tank Maintenance	Minimum Analysis Time
1	Acid cleaner solution	Dynachem	200 ml/l	190-250 ml/l	1 week
		LAC-41 tap water	Remainder		
3	Sodium Persulfate solution	Sodium persulfate	120 g/l	100 - 140g/l	2 weeks
		Sulfuric acid reagent grade	12, 32 ml/l		
		Deionized or distilled water	Remainder		
5	Phosphoric acid solution	Phosphoric Acid	20 ml/l	Dump every 2 weeks	N/A
		Tap water	Remainder		

PROCESS SPECIFICATION
FOR IMMERSION TIN PLATING

1. SCOPE

1.1 Scope. This specification describes an immersion tin plating process which is to be used to cover all exposed copper termination pads and conductive circuitry on rigid-flex printed wiring cables.

2. APPLICABLE DOCUMENTS

WS 4445 (current issue)

3. REQUIREMENTS. In order to perform the immersion tin plating process, specific types of equipment, materials, and procedures shall be incorporated to produce a deposit which conforms to those requirement specified in WS 4445. Listed below are the basic items to perform the process at a level acceptable to the procuring activity.

3.1 Equipment. Individual pieces of equipment may differ from those specified below providing it can be demonstrated that they perform equal to or better than the ones specified for the operation.

3.1.1 Tanks. Tanks used to hold the cleaner, water rinses, sodium persulfate, phosphoric acid, and immersion tin solutions shall conform to the following and shall provide sufficient volume, dimension, and freeboard to contain parts for which the process is intended.

- Cleaner tank - The tank which holds the cleaning solution shall be constructed of a material which resists attack from acid cleaners and which can withstand the temperatures specified for use (See Table 1). Polypropylene, or coated (polyvinyl chloride-acceptable) steel tanks are adequate, providing the wall thickness will support the volume of solution contained.

- Water rinse tanks (room temp). The tank shall be constructed of a material which does not rust, corrode, degrade, or produce a product which is detrimental to the hardware being processed. Stainless steel, epoxy glass, coated steel, polypropylene, or polyvinyl chloride are adequate providing the wall thickness will support the volume contained. The rinse tank should contain a weir and drain pipe to allow skimming of surface contamination and circulation.

- Water rinse tanks (heated). In addition to the requirements for a room temperature rinse tank the materials used for construction shall

withstand temperatures shown in Table 1. Stainless steel is the most commonly used material in this application.

- Tanks for sodium persulfate and phosphoric acid solutions. These tanks shall be constructed of a material which will not degrade or produce a product which is detrimental to the hardware being produced, when exposed to the solution contained. Polypropylene or polyvinyl chloride are acceptable materials for this application.

- Immersion tin plating tank - The immersion tin plating tank shall be constructed so that a liquid heating medium is used in a secondary tank surrounding the tank containing the plating solution in order to provide uniform heating (opposed to localized heating). The secondary tank may contain built-in or over-the-side immersion type heaters. Materials used for the primary and secondary tanks shall be compatible with the liquids contained. Secondary tanks may be constructed of polyproylene or stainless steel and primary tanks may be constructed of coated stainless steel.

3.1.2 Heaters. Heaters for both the cleaner and hot water rinses may be of the over-the-side immersion type. The heaters shall be constructed to provide sufficient heating capacity and also adequate resistance to chemical attack. A temperature control device shall be provided to maintain temperatures specified in Table 1.

3.1.3 Air compressor or dryer. The source of compressed air must be such that the subject hardware can be dried without leaving any oil or other residue on the surface. If an air compressor is used it must contain a filter to assure oil removal.

3.1.4 Racks. Racks shall be constructed of a material which will not degrade the chemical solutions, and that will not become degraded. They shall be constructed so as to provide separation of cable layers for exposure during processing. The geometry of the rack shall not cause solution dragout or transfer from processing tank to tank. Acceptable types of material are Teflon, polypropylene, or stainless steel.

3.2 Materials. The materials listed below produce a tin plating which conforms to the requirements specified in WS 4445. If other chemical solutions are used it must be demonstrated that the resulting tin plating conforms also.

3.2.1 Material storage. Chemicals shall be stored in a safe, dry, temperature controlled area. Containers used for chemicals shall protect the materials, surrounding environment, and personnel from damage, degradation, or harm.

3.2.2 Process solutions. Make-up and control of chemical solutions used in this process shall be controlled as specified in Table 2 in the Appendix.

3.2.3 Basic dhemicals

3.2.3.1 Shipley, LT-26 tin salts

3.2.3.2 Hydrochloric acid, reagent grade

3.2.3.3 Dynachem LAC-41 acid cleaner

3.2.3.4 Sodium persulfate

3.2.3.5 Sulfuric acid

3.2.3.6 Phosphoric acid

3.3 Required procedures and operations. The following table contains all required operations and procedures for applying immersion tin plating.

TABLE 1

No.	Operation and/or Solution	Temperature	Time
1	Immerse cable in acid cleaner	140-160°F	30-40 seconds
2	Rinse in running tap water	Room	50-60 seconds
3	Immerse cable in sodium persulfate solution	Room	20-30 seconds
4	Rinse in running tap water	Room	60-75 seconds
5	Immerse in phosphoric acid solution	Room	20-30 seconds
6	Rinse in running tap water	Room	30-40 seconds
7	Immersion tin plate	165 ±15°F	20-30 seconds
8	Rinse in hot water	180-212°F	1-3 minutes
9	Rinse in running tap water	Room	1-3 minutes
10	Dry with filtered compressed air or in blown air drier		As required

Note: As specified in WS 4445, test samples shall be processed with each lot of cables and the acceptability of the processed hardware shall depend on the test results.

3.4 Recommended procedures and operations

3.4.1 As the cable is processed in 3.3 the panel should proceed through steps 1 through 9 without drying.

3.4.2 During transfer of the cable from tank to tank the operator should dwell over each solution long enough to minimize solution transfer.

3.4.3 The cable should be racked in a position which provides exposure of all individual pads on all cable layers.

3.4.4 The operator processing the cable should observe the following:

1) Copper terminal pads and circuit patterns for intended plating are clean and bright after step 5 in 3.3

2) Features tinned after step 7 in 3.3 are completely covered with tin plating

3) No salts remain on cable after step 10 in 3.3

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. The supplier (fabricating the cable) is responsible for all inspection operations. At the option of the procuring activity, additional in-process or final inspection may be performed by their personnel when deemed necessary.

4.2 Monitoring procedures for equipment. The supplier shall perform periodic surveillance of equipment to assure that damage or degradation to the equipment is not causing discrepant hardware to be produced. Items to be monitored include:

1) Process tanks maintain solution levels (no leaks)

2) Process tanks are not rusting, corroding or otherwise deteriorating

3) Heaters maintain solution temperatures and are not deteriorating

4) Temperature controllers are calibrated periodically and maintain temperatures specified in Table 1

5) There is no contamination in or floating on process solutions or rinses.

4.3 Monitoring procedures for materials. Materials used in this process are primarily chemical solutions. Table 2 in the appendix describes solution make-up proportions and maintenance requirements. In addition the table specifies the period for analyzing each solution or the period of use (life of the bath). Analyses procedures shall be provided by chemical suppliers.

4.4 Test methods. The test procedures are fully described in WS 4445. The samples and sample size specified in WS 4445 shall be used for all tests performed.

6. NOTES

6.1 Intended use. The immersion tin plating process provides a thin plating on all exposed terminal pads and conductors of flexible and rigid-flex printed wiring cables for the purpose of promoting solderability and providing a minimum protection against oxidation. An added benefit is that it helps detect adhesive on solderable areas during inspection.

Table 2
APPENDIX

Operation	Solution	Material	Make-up Quantity	Tank Maintenance	Minimum Analysis Time
1	Acid cleaner solution	Dynachem LAC-41	200 ml/1	190-250 ml/1	1 week
		Tap water	Remainder		
3	Sodium persulfate solution	Sodium persulfate	120 g/1	100-140 g/1	2 weeks
		Sulfuric acid reagent grade	12.32 ml/1		
		Deionized or distilled water	Remainder		
5	Phosphoric acid solution	Phosphoric acid	20 ml/1	Dump every 2 weeks	N/A
		Tap water	Remainder		
7	Immersion tin plating solution	Shipley LT-26 tin salt	150 g/1		1 week
		Hydrochloric acid	50 ml/1		
		Deionized or distilled water	Remainder		
					Tin crystallization pint 130 - 145°F pH 0.5 to 0.75

END

AD-A095 045 GENERAL DYNAMICS CORP POMONA CA POMONA DIV F/G 9/5
RIGID-FLEX PRINTED CIRCUIT MANUFACTURING PROCESS. A PROJECT OF --ETC(U)
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9 June 1981

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NOSC TR 531

RIGID-FLEX PRINTED CIRCUIT MANUFACTURING PROCESS, A Project of the Manufacturing Technology Program Naval Sea Systems Command, Final Report 30 June 1979, by JA Reavill (General Dynamics).

LITERATURE CHANGE

1. Please insert the attached 3 pages (Listing of Exhibits) into the copy or copies of this report you are presently holding.

LISTING OF EXHIBITS

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